United States Department of Agriculture
Soil Conservation Service-Research

Leaching Studies
In Connection With
Drainage of Saline Soils
In
The Imperial Valley
California

(Provisional)

by

GEORGE B. BRADSHAW
Drainage Engineer

WILLIAM W. DONNAN
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Under the supervision of
HARRY F. BLANEY
Research Project Supervisor

Prepared under the direction of
GEORGE D. CLYDE, Chief

Division of Irrigation Engineering and Water Conservation
Soil Conservation Service-Research

Los Angeles, California
May, 1953

UNITED STATES DEPARTMENT OF AGRICULTURE
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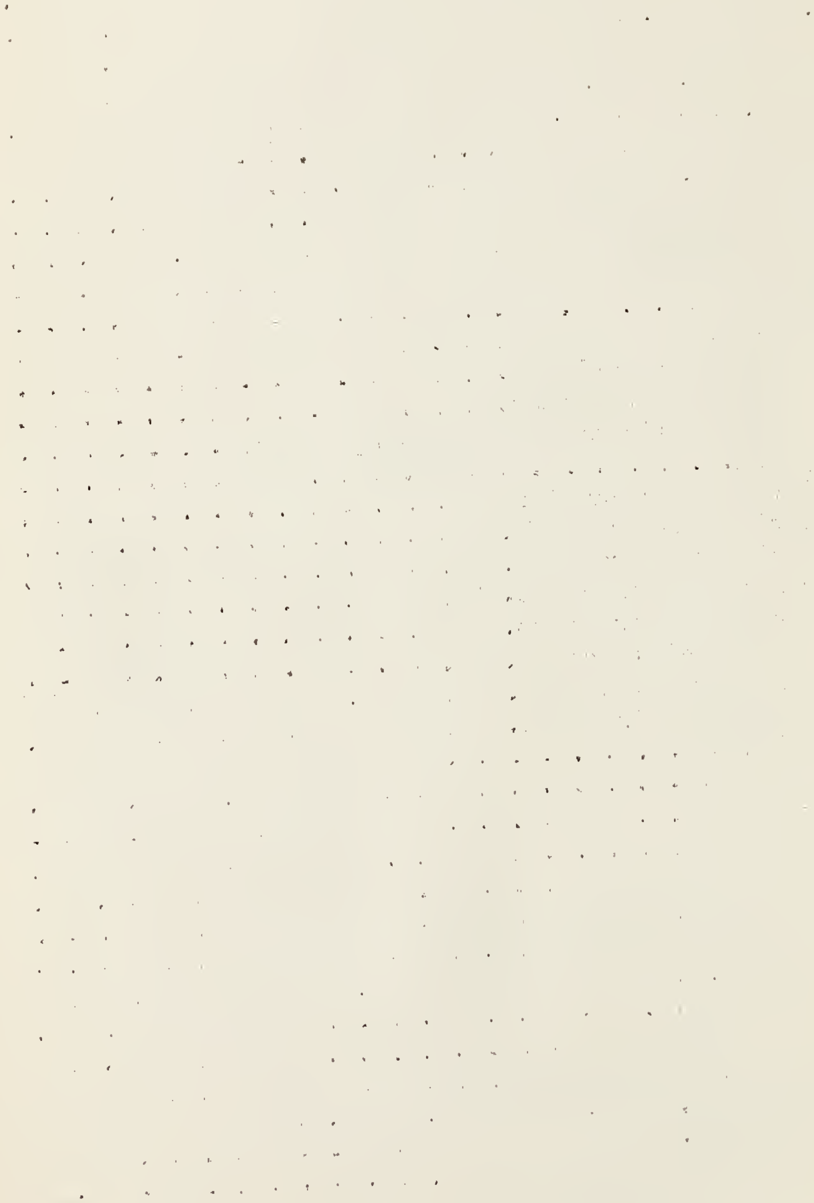

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FOREWORD

Under a cooperative agreement between Soil Conservation Service-Research, U. S. Department of Agriculture, and the Imperial Irrigation District, State of California, funds were provided in 1941 to inaugurate a comprehensive drainage research investigation in Imperial Valley. One phase of the drainage research program dealt with leaching and reclamation of waterlogged areas. The field studies were concluded in 1951.

This report contains a detailed account of the various leaching and reclamation studies conducted by the Division of Irrigation Engineering and Water Conservation of the Soil Conservation Service in cooperation with the Imperial Irrigation District, at various times over a period of ten years.

The results and findings of leaching and alkaline reclamation investigations in one valley are sometimes difficult to apply to other areas due to the vastly complex inter-relationship of soils, waters and crops in the different valleys and basins of the west. However, it is believed that the procedure and results presented in this report and some of the conclusions reached in Imperial Valley will be useful in solving drainage and leaching problems elsewhere.

Harry F. Blaney
Research Project Supervisor

ACKNOWLEDGMENT

The authors have drawn freely from various annual progress reports of the Imperial Valley drainage investigations to compile this manuscript. The work of Willis C. Barrett, William W. Fox and V. S. Aronovici, members of the Soil Conservation Service Research staff, assigned to the Imperial Valley Project during the early years of the study, and of W. T. Gish, during the last three years of the study, is hereby acknowledged.

Acknowledgment is also made of the cooperation of A. C. Bowen, District Conservationist, and the Imperial Work Group Staff of the Operations Division, Soil Conservation Service, who assisted with many of the field measurements.

A major share of the chemical analysis work was done in the Testing Laboratory of the Imperial Irrigation District. The splendid cooperation afforded by Elmer Hartzog, Superintendent of Construction and Maintenance, Robert Reynolds, Drainage Engineer, and Russell Trexler, Laboratory Analyst, and other members of the District Staff made possible many of the findings and results.

The salt balance studies at Meloland Experiment Station were originally conceived and inaugurated by Walter W. Weir and L. G. Gear of the University of California. Their helpful assistance on this and other phases of the study is hereby acknowledged.

Acknowledgment is made of the helpful consultation afforded by members of the staffs of the Regional Salinity Laboratory and the Roubidoux Laboratory of the Bureau of Plant Industry, Soils and Agricultural Engineering, United States Department of Agriculture and the Citrus Experiment Station of the University of California, all of Riverside, California.

Finally, the authors wish to acknowledge the helpful assistance of the Imperial Valley Drainage Committee under whose guidance and constructive review the various investigations were conducted. This advisory committee included the following representatives of the cooperating agencies:

W. W. McLaughlin..Chairman
Evan T. Hewes........................Imperial Irrigation District
John S. Barnes........................Soil Conservation Service
George D. Clyde..............Soil Conservation Service, Research
M. J. Dowd........................Imperial Irrigation District
A. E. Backman................................Federal Land Bank
Walter W. Weir........................University of California
B. A. Weiss........................Imperial Irrigation District
Harry F. Blaney..................Technical Advisor and Secretary

CONCLUSIONS AND RECOMMENDATIONS

The problem areas of the Imperial Valley are generally characterized by a high water table condition. A saline concentration in the root zone generally accompanies, and is a result of, the high water table. This salinity content ranges from about 18 tons per acre-foot in light soils to 300 or more tons per acre-foot in the surface foot of fine textured clay soils.

Permanent economical reclamation of Imperial Valley saline soils has been effected on farms where adequate tile drainage was installed and reclamation practices were carried out. The following are some conclusions and recommendations resulting from the leaching research:

1. Drainage must be adequate before permanent reclamation can be effected. Partial leaching of toxic salts can be performed without artificial tile drainage; however, the reclamation is only temporary and will have to be repeated at intervals of 1 to 5 years.

2. Tile drainage has three functions: "A" - To remove saline elements during leaching; "B" - to maintain the ground water at a safe level during normal irrigations; and "C" - to remove the saline elements that tend to return to the surface from below the tile drainage system following leaching.

3. Fine textured clay soils having an average or prorated permeability of 0.6 cc/sq/cm/hr or less have proved uneconomical for tile drainage, because of the close spacing of laterals required for adequate drainage. The best reclamation practice on these fine textured soils is careful management with respect to leveling and use or efficiency of irrigations. Fields should be border irrigated or flood irrigated rather than irrigated with furrows.

4. Reclamation has been profitable in the Imperial Valley. On some tracts of reclaimed land the increase in crop production due to tile drainage and leaching has been sufficient to pay for the reclamation costs the first year. The improvement of fine textured soils is not as spectacular as the improvement on coarse textured soils. Consequently, reclamation practices over a longer period of time are required in the fine textured soils.

5. Two leaching periods, of about 30 days each tend to remove more saline elements via the drainage system for the same total ponding time than one 60-day leaching period. This is due to a greater portion of the drainage effluent originating at greater distances from the drainage laterals.

6. Long leaching periods tend to remove saline elements to greater depths than short periods. A 100-day leaching period will remove the saline elements to a greater depth than will four 25-day ponding periods.

7. The percentage of water removed by a properly functioning tile drainage system increases over a period of years. This increase in drainage efficiency may be due to the removal of saline elements and the establishment of minute channels or waterways to the tile lines. This improves the drainage and enables the drainage system to lower the water table a shorter period of time.

8. There is some soil erosion in the form of removal of colloidal clay in the leaching ponds during leaching. The colloidal clay at the soil surface is picked up by the leaching water and removed from the field by the surface water. There is also some movement and segregation of the coarser sediments during the leaching period.

9. The application of gypsum was found to have no effect upon the infiltration rate or permeability of Imperial Valley soils.

10. The application of a detergent or wetting agent had a slight effect upon the permeability of fine textured soils; however, the increase was so slight that its use under present prices would prove uneconomical. The detergent used, a sulphonated ester of ethyl alcohol, also had a toxic effect upon plants used in the tests.

11. For newly reclaimed land it is recommended that crops be grown which can be border irrigated or flooded rather than furrow irrigated. As much of the reclaimed field as possible should be under water during irrigations. The furrow or border ridges act as wicks and water evaporating from them tends to build up the salt content of the soil.

12. Newly reclaimed land should be kept under production the year round and not allowed to lie idle over the summer during the first few years. This prevents saline elements from returning to the surface by capillary action. By planting a crop of sesbania or clover during the summer and plowing it under, the land remains in production and, at the same time, nutrients and humus are being added to the soil.

LEACHING STUDIES IN CONNECTION WITH DRAINAGE OF SALINE SOILS IN THE IMPERIAL VALLEY, CALIFORNIA

by

George B. Bradshaw
and
William W. Donnan

INTRODUCTION

The objective of this publication is to describe the practices that were used in the Imperial Valley for reclaiming saline soils, and to make the information available for use in other places where conditions are similar.

A large part of the land of the Imperial Valley is highly productive; however, in some areas production is low due to poor drainage and concentrations of toxic soluble salts. Water from the Colorado River used for irrigation contains about one ton of salts per acre-foot of water. With the removal of water by evaporation and transpiration these salts tend to accumulate in the root zone of the soil. Some areas of the valley which were at one time quite productive have been abandoned because of the development of saline conditions. In other areas the saline elements were present in the surface soils prior to farming operations. A combination of poor drainage and waterlogged land coupled with relatively high concentrations of saline elements in the irrigation water has produced areas that require reclamation.

Early studies by Hilgard on arid irrigated land in California (4) 1/ revealed that the unproductivity of "alkali" soils is due to the accumulation of excessive soluble salts and that various types of salts produce different degrees of plant injury. Alkali land is classified into two groups: (1) white-alkali or saline soils containing such salts as chlorides and sulfates of calcium, magnesium and sodium; and (2) alkaline soils containing salts of sodium carbonate and sodium bicarbonate. The majority of the salts in the soils of Imperial Valley are of the saline type and require no addition of chemical amendments such as gypsum or sulfur for effective leaching and reclamation as do the alkaline soils.

The solution to this problem lies in the installation of adequate tile drainage systems to lower the free ground-water table and in the removal of excess salts out of the soil profile by ponding water on the surface and leaching. Leaching in conjunction with tile drainage has proved to be the most economical reclamation of saline soils in Imperial Valley.

1/ Figures in parenthesis refer to Literature Cited.

There are various methods of leaching saline soils. On coarse textured soils the problem is fairly simple; the soils may be reclaimed in 30 days or less of leaching or even by applying excessive amounts of irrigation water. On fine textured soils perhaps four or five years of leaching and land management may be required to reclaim the soils and restore them to a high level of production.

The investigation herein reported was made over a 10-year period to determine the best methods of restoring the saline soils in the Imperial Valley to normal production. The results are reported in detail in the hope that the findings can be used in the reclamation of saline soils in other irrigated areas of the West.

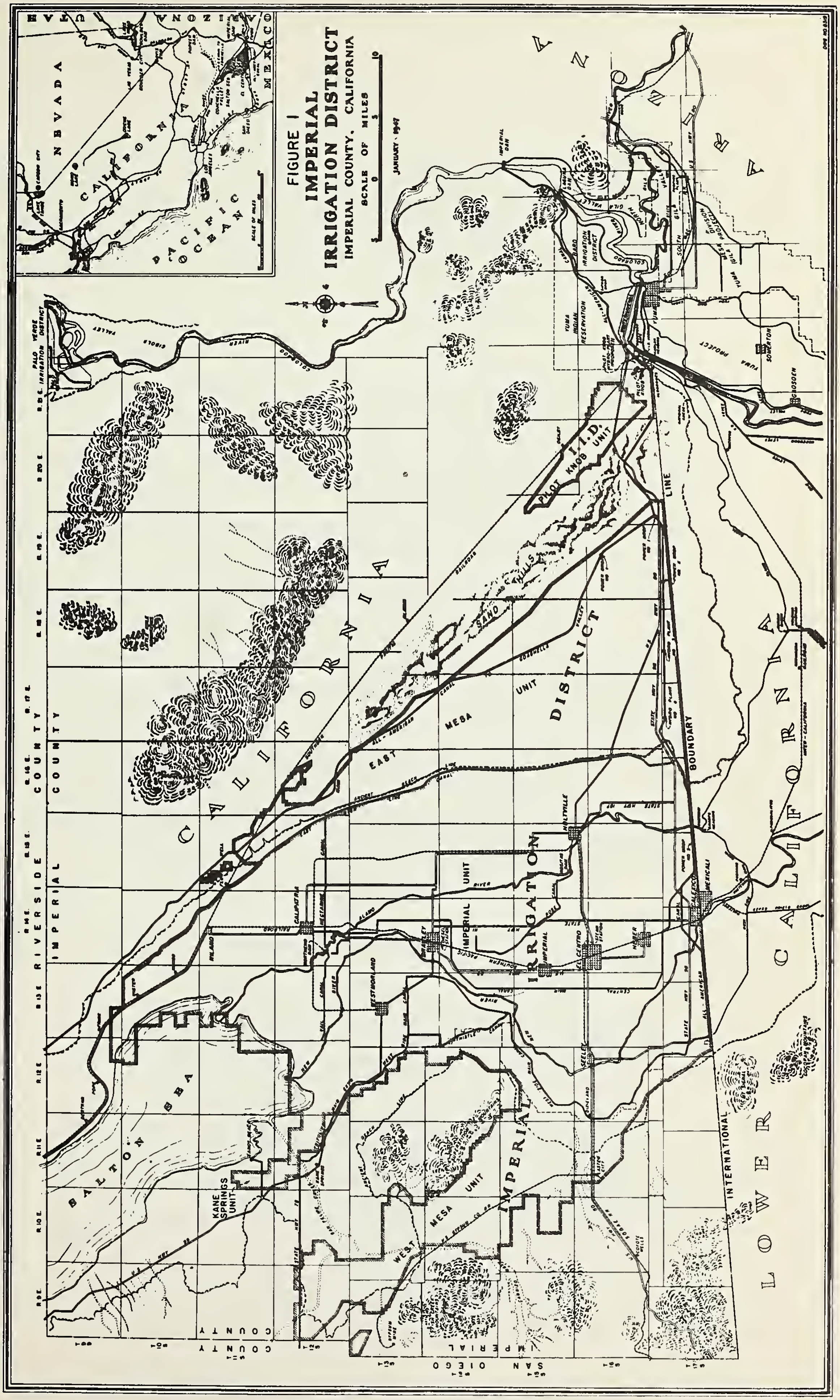
GENERAL CHARACTERISTICS OF IMPERIAL VALLEY

The Imperial Valley is located in the extreme southeast portion of California and includes almost all of the agricultural land in Imperial County (figure 1). The investigation was concerned only with that land within the Imperial Irrigation District which extends north from the International Boundary about 45 miles to the Salton Sea. The area, which has an average width of about 25 miles, lies roughly between the East High Line and the West High Line Canals.

The valley is a graben which has been gradually depressed and, at the same time, encroached upon by the Colorado River delta. The river flow has intermittently swung north into the Salton Sea Basin and south into the Gulf of California. This has produced a delta ridge with an approximate elevation of 40 feet above sea level which closes off the Salton Basin from the Gulf of California. The maximum depth of the basin is about 271 feet below Pacific sea level. The present Salton Sea level is about 239 feet below Pacific sea level.

Soils

During recent geological time when the Colorado River flowed alternately into the basin, raising the level of the lake occupying it, and into the gulf, permitting evaporation to shrink the lake, sediments were deposited in varying locations, sequences and thicknesses that depended upon the vagaries of the river and the fluctuations of the lake level. It is assumed that each time the lake receded the newly exposed sediments developed sun cracks. Wind action may have filled these cracks with sand and, in some instances, may have built dunes upon them before the next inundation occurred. Earthquake fault lines also had an effect upon the soil by fracturing the soil along stress lines. These stress lines were



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filled with sand from below in the resulting compressional waves. Thus, the formational elements were present for a highly complex body of stratified soil material as well as for structural conditions that confuse the picture of soil moisture relations. However, some strata do exist that are consistent in thickness and continuous over an area of many acres.

Depth of sediments

The following tabulation gives the depths to which several oil companies drilled test holes in the Imperial Valley.

1. Standard Oil Company's exploratory well drilled in 1946 in the San Felipe Hills - depth of hole 5,500 feet; bedrock 5,100 feet.
2. Armada Oil Company's exploratory well 1/2 mile west of Heber - depth of hole 7,300 feet; no bedrock.
3. Armada Oil Company's exploratory well 2 miles north of Brawley; depth 7,400 feet; no bedrock.
4. Shell Oil Company's exploratory well, near Truck Haven - depth 6,100 feet-in conglomerate - estimate 100 ± feet to bedrock.
5. Texas Oil Company's exploratory well 2 miles south of Holtville - depth 12,300 feet; no bedrock.

From these holes it would appear that there are upwards of two miles of unconsolidated fill in parts of the Imperial Valley.

Soil series

The five principal soil series (6) (8) of the Imperial Valley are as follows:

1. Imperial. Both the surface soil and the subsoil of the Imperial series are fine textured and calcareous. Stratification is a common condition, thin layers of sandy material often separating layers of fine textured soil.
2. Holtville. The surface soil of the Holtville series is identical with that of the Imperial series, invariably of fine or at least medium texture. There is considerable variation in the depth of the surface soil, but the material below it is predominantly of coarser texture and is generally loose and sandy. The soil is calcareous.

3. Meloland. The Meloland soil is a Holtville upside down. The surface soil is generally loose, and pervious, coarse textured, and the subsoil is fine textured, compact, often stratified, and relatively impervious. Actually, the Meloland is an Imperial or Holtville soil with a cap of windblown fine sandy material. It is calcareous throughout.

4. Rositas. The surface soil of the Rositas is identical with that of the Meloland, where as the subsoil is like that of the Holtville. The soil profile is loose, pervious, and coarse textured to a depth of six feet or more. It is calcareous. Both wind and water have doubtless been involved in the deposition of this soil, and the areas that have not been leveled for cultivation are marked by dunes and hummocks.

5. Hiland. The Hiland soils occupy alluvial fans below the level of the old beach lines. The surface soils are porous and mostly coarse textured and represent a layer of desert wash varying in depth from a few inches to 3 feet. A desert pavement is common on the surface. The subsoils consist of thinly bedded strata of fine materials of water-laid origin. The subsoils are relatively impervious and, when dry, have a shaly character. The soil is calcareous throughout.

Climate

Climatically, Imperial Valley is characterized by low annual rainfall, low humidity, and high summer temperatures. Table 1 gives climatological data for three stations in the Imperial Valley.

Table 1 - Imperial Valley climatological data

Station	Length of records	Average annual precip.	Temperature: Annual ave.	January: Ave.	January: Ave. min.	July: Ave.	July: Ave. max.	Highest	Lowest	Days between last frost and first frost
	Years	Inches	F°	F°	F°	F°	F°	F°	F°	No.
Brawley	28	2.43	70.8	52.7	36.2	91.1	105.9	121	19	303
Calexico	21	3.18	71.0	53.2	38.9	89.8	103.9	117	21	311
Imperial	21	3.35	71.9	53.6	37.0	91.9	106.0	124	16	311

Salt Problem

All farming in Imperial Valley is done by irrigation, the annual precipitation of 3 inches being sufficient to support desert flora only. Water for irrigation was first brought by canals from the Colorado River in 1901. The presence of a large body of sand dunes on the American side of the international boundary and a natural channel on the Mexican side resulted in the choice of the Mexican route for the main canal. That route was used until the 80-mile All-American Canal was completed in 1942. The All-American Canal brings water to the southern end of the valley. It is taken northward by three main canals which branch into a network of distributories delivering water to the high corner of each 160-acre tract. The District owns and operates about 2,000 miles of irrigation canals.

The suitability of water for irrigation has been classified by various investigators (7). The measurable characteristics used to classify irrigation waters are: conductance, parts per million of total salts, tons of dissolved salts per acre-foot of water, parts per million of chlorides, parts per million of boron, and the sodium percentage. Table 2 shows the tolerance range for the three classes of water. (7)

Table 2 - Tolerance table of classes of water used for irrigation

Item	Units	Class 1 Excellent - Good		Class 2 Good - Injurious		Class 3 Injurious-Unsatisfactory	
Conductance	$Kx10^5$	Less than	100	100	300	More than	300
Total Salts	P.P.M.1/	Less than	700	700	2000	More than	2000
Total Salts	T.A.F.2/	Less than	0.95	0.95	2.70	More than	2.70
Chlorides	P.P.M.	Less than	248	248	426	More than	426
Boron	P.P.M.	Less than	0.5	0.5	2.0	More than	2.0
Sodium	Percentage	Less than	60	60	75	More than	75

1/ Parts per million.
2/ Tons per acre-foot of water.

The range of chemical analysis for the irrigation water, drainage water, artesian well discharges, vertical drainage wells, springs and river water samples from the Imperial Valley is given in table 3. The

Table 3. Range of chemical analysis of irrigation and drainage waters from the Imperial Valley, California.

Sample No.	Type [1]	Conductance	Total	Salts	Anions CO_3	Anions HCO_3	Anions SO_4	Anions Cl	Anions NO_3	Anions Total	Cations Ca	Cations Mg	Cations Na	Cations K	Cations Total	Sodium	Boron
		Kx10[5]	P.p.m.	T.a.f.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	Percent	P.p.m.
1	I	106	770	1.04	0	177	280	92	-	549	90	34	92	-	216	35	0.5
2	I	100	696	0.94	0	159	267	85	-	511	94	30	78	-	202	32	.5
3	D	252	1,857	2.51	0	445	645	222	-	1,312	194	62	280	-	536	45	
4	D	1,539	17,680	17.68	0	738	4,051	3,621	-	8,410	817	625	2,449	-	3,891	54	
5	D	4,180	34,640	46.81	0	378	6,623	15,620	-	22,613	1,733	1,379	8,842	-	11,954	66	
6	D	6,721	83,890	113.36	0	189	2,137	51,475	-	53,801	7,491	4,551	17,251	-	29,293	50	
7	A	113	696	0.94	0	421	73	124	-	618	0	3	268	-	271	98	.65
8	A	516	3,197	4.32	27	353	605	1,195	9	2,189	20	35	1,132	-	1,187	93	8.2
9	A	849	5,610	7.58	0	320	1,530	1,810	9	3,669	182	106	1,646	-	1,934	80	6.5
10	W	119	881	1.19	0	198	312	114	-	624	97	34	122	-	253	41	.3
11	W	132	918	1.24	0	189	310	142	-	641	81	35	153	-	269	49	
12	S	410	3,152	4.26	0	1,324	128	703	-	2,155	37	40	897	-	974	88	1.8
13	S	406	2,516	3.40	trace	311	486	923	-	1,720	86	42	769	-	897	81	3.2
14	R	269	1,739	2.35	-	195	747	540	C.04	1,482	156	78	454	-	688	58	
15	R	367	2,412	3.26	-	201	589	808	5	1,603	190	100	474	-	764	54	

1/ I - Irrigation
D - Drain
A - Artesian
W - Well
S - Spring
R - River

Water sample locations

1. Central Main Canal sampled Nov. 2, 1950
2. East Highline Canal sampled Sept. 12, 1949
3. Tile drainage effluent T17S R15E Sec. 1
4. Tile drainage effluent T14S R14E Sec. 13
5. Tile drainage effluent T14S R15E Sec. 26
6. Tile drainage effluent T14S R14E Sec. 33
7. Artesian well T15S R16E Sec.26 sampled Dec. 22, 1949
8. Artesian well T13S R15E Sec. 1 sampled Apr. 16, 1948
9. Artesian well T12S R15E Sec.4 sampled Sept. 15, 1948
10. Verticle drainage well T16½S R12E Sec. 2 sampled July 31, 1950
11. Verticle drainage well T16S R16E Sec. 1 sampled June 1, 1950
12. Spring T14S R16E Sec. 8 sampled Jan. 16, 1951
13. Spring T12S R11E Sec. 20 sampled Jan. 24, 1949
14. New River outlet sampled March 1946
15. Almo River at North End Dam sampled Feb. 29, 1950

irrigation water used in the Imperial Valley is on the borderline of class 1 and 2 water with respect to conductance, boron, and total salts; however, the chloride, and sodium content place it in a class 1. A comparison of the irrigation water analysis in table 3 with the tolerance classes in table 2 shows that the irrigation water falls in the following categories:

Item	Units	Water analysis			Class rating
Conductance	$Kx10^5$	100	-	106	Borderline class 1 - 2
Total salts	T.A.F.	0.94	-	1.04	Borderline class 1 - 2
Chlorides	P.P.M.	85	-	92	Class 1
Boron	P.P.M.			0.5	Borderline class 1 - 2
Sodium	Percentage	39	-	43	Class 1

Without adequate drainage in the Imperial Valley the relatively high saline irrigation water tends to build up the saline content of the soil. Over a period of 5 to 10 years the salinity of a poorly drained area may reach such a high level that crop growth is retarded. In extreme cases such an area would have to be abandoned for crop production because of the high saline content of the surface soil.

Salt Balance

During the past eight years the Imperial Irrigation District has maintained records on the salt balance in the Imperial Valley. Periodic samples were taken from the All-American Canal and the waste ways in conjunction with metering the water. The total quantity of dissolved salts entering the valley in the irrigation water and the salts being discharged into the Salton Sea were computed from the chemical analysis and the related volumes of irrigation and drainage waters. The salt balance within the Imperial Valley is determined by comparing the quantity of salt leaving the valley in the drainage water with that entering in the irrigation water.

Salt-balance conditions for the 8 years 1943 to 1950 inclusive are summarized in table 4. The third column shows the ratio between inflow and outflow of saline elements. The figures indicate that the salt balances for the years 1949 and 1950 were more favorable than any of the previous years. The favorable ratios of 105.30 percent for 1949 and 104.93 percent for 1950 are attributed to an increase in reclamation of saline soils by tile drainage and leaching.

Table 4 - Ratio between the total annual amount of saline elements entering Salton Basin and annual amount deposited in Salton Sea, Imperial Valley, California.

Year	Saline elements entering Salton Basin from Colorado River	Saline elements deposited in Salton Sea	Ratio	Area leached during year
	Tons	Tons	Percent	Acres
1943	2,157,208	1,997,390	92.59	4,027
1944	2,554,432	2,242,920	87.80	6,531
1945	2,563,579	2,400,629	93.64	8,888
1946	2,907,275	2,395,904	82.41	10,637
1947	2,799,511	2,440,809	87.19	8,885
1948	2,744,146	2,630,608	95.86	10,787
1949	2,659,119	2,800,165	105.30	20,000
1950	2,793,780	2,931,431	104.93	18,356

With the increase of tiled acreages and the increase in acres being leached a greater amount of salt was removed from the land and discharged into the Salton Sea. The total acreage of 18,356 acres leached during 1950 was on 204 farms which ranged in size from 640 acres down to 2 acres.

Drainage in Imperial Valley

The drainage problem and resultant saline accumulations became apparent in the valley as early as 1915. Early day attempts to drain the valley lands consisted mainly of open drains. The open drainage system of the valley consists of a network of drains ranging in depth from 6 to 14 feet and spaced in a grid averaging almost a drain every halfmile. There are now about 2000 miles of open drains in the valley. In 1905 the Colorado River flooded the canal diversion intakes and the entire river flowed northward into Salton Sink for two years. This flow produced the present Salton Sea. The flow also enlarged the channels of the New and Alamo Rivers enormously and they have since acted as main trunk drainage outlets carrying the flow from the open drains. In recent years the flow into Salton Seas has been greater than the evaporation therefrom and the water level of the Sea has been rising.

In 1929 the first underground drainage systems were installed when 5.56 miles of tile lines were laid. During subsequent years more and more tile drains have been installed until at the present time there are over 2500 miles of tile lines draining an estimated 120,000 acres of land in Imperial Valley. Table 5 shows the amount of tile installed for each year since the first lines were placed in 1929.

The locations of the areas tiled in the Imperial Irrigation District, California as of December 31, 1950 is shown in figure 2. About 20 percent of the irrigated land of the valley was at that time being served by tile drainage systems. It is estimated that approximately 60 percent of the irrigated area of the valley will eventually need artificial drainage.

PREVIOUS INVESTIGATIONS

At various times since 1901 the United States Department of Agriculture and the Agricultural Experiment Station of the University of California have made investigations in Imperial Valley.

The United States Department of Agriculture, Division of Irrigation, (Irrigation Investigations) has made the following types of research studies in the past: Cooperative investigations on irrigation and sedimentation, 1907-08; wells and water levels, 1913; seepage and drainage, 1914; irrigation requirements, 1915-17; sedimentation, 1917-27, and water supply, irrigation and drainage, 1933.

Beginning in 1901 the Bureau of Soils of the United States Department of Agriculture and the A gricultural Experiment Station of the University of California made several soil surveys of Imperial Valley. The experiment s tation also made studies of reclamation of alkali soils and drainage. A soil salinity study on several test plots has been conducted by the University of California Citrus Experiment Station for a number of years.

For many years the Bureau of Plant Industry of the United States Department of Agriculture has accumulated data on mineral content of Colorado River water.

Long-period ground-water records have been kept on numerous observation wells by the Imperial Irrigation District. A mass of other information on drainage and irrigation has been recorded by the District since it was organized in 1915.

During 1929-31 (9) Edward E. Thomas, University of California, conducted some experiments on the reclamation of saline soils in the El Centro area in the Imperial Valley. These studies consisted of ponding water on various treated and untreated plots for a period of 95 days. They were made on plots which did not have tile drainage. There was a marked increase in crop production on the plots for 2 years following the reclamation.

Table 5 - Tile installation progress in Imperial Valley, California for the years 1929 to 1950 inclusive

Year	Miles installed each year	Accumulated mileage	Acres tiled	Accumulated acreage tiled
1929	5.56	5.56		
1930	11.97	17.53		
1931	2.69	20.22		
1932	2.30	22.52		
1933	24.03	46.55		
1934	3.52	50.07		
1935	3.49	53.56		
1936	20.01	73.57		
1937	33.65	107.22		
1938	68.88	176.10		
1938	60.71	236.81		
1939	57.30	294.11		
1939	38.66	332.77		
1940	18.24	351.01		
1940	48.60	399.61		
1941	46.08	445.69		
1942	37.15	482.84		
1943	53.24	536.08		
1944	60.00	596.08		
1945	55.00	651.08		
1946	133.25	784.33	5,480	35,720
1947	325.00	1,109.33	17,920	53,640
1948	393.80	1,503.13	17,220	70,860
1949	455.62	1,958.75	21,670	92,530
1950	458.00	2,416.75	22,610	115,140
Total	2,416.75			115,140

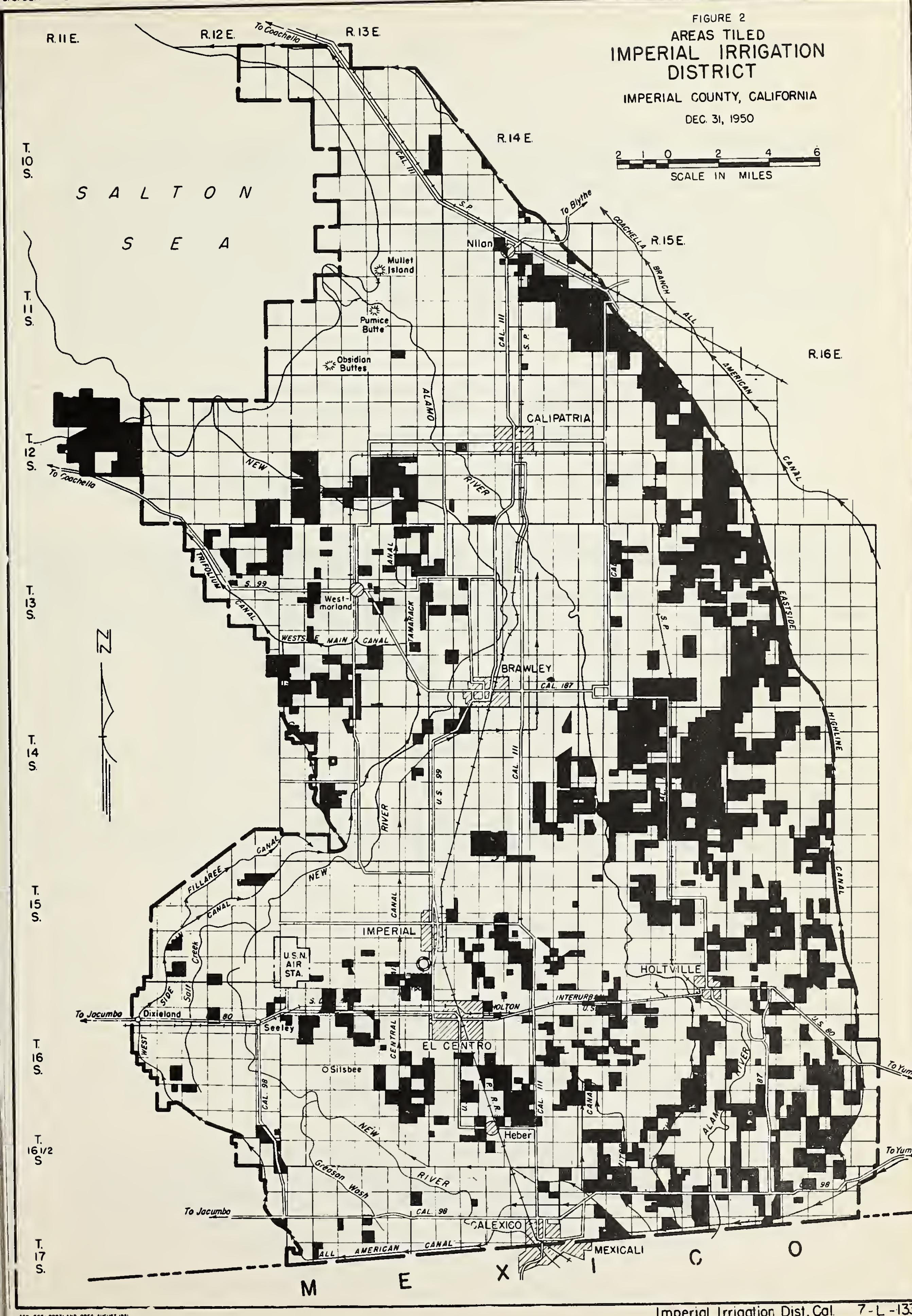


FIGURE 2
AREAS TILED
IMPERIAL IRRIGATION DISTRICT
IMPERIAL COUNTY, CALIFORNIA
DEC. 31, 1950

The production during the third year started to decline. The soils were silty clay to a depth of $8\frac{1}{2}$ to $9\frac{1}{2}$ feet and this was underlain with a sandy layer 3 feet or more in thickness. The water table had risen to within 18 inches of the surface, where it remained until a drain ditch was dug 2000 feet away. The ditch penetrated a sandy layer which lowered the water table to a depth of 4 to 5 feet from the ground surface. To further facilitate the subsurface drainage, a lateral ditch was dug within 200 feet of the experimental tract. One of the tables taken from Bulletin 601, "Reclamation of White-Alkali soils in the Imperial Valley" by Edward N. Thomas is given in table 6.

The analysis shows that some reclamation was accomplished without tile drainage. It seems apparent that these plots would have become saline again if the open drains had not been installed.

Table 6 - Water-soluble salts in soil from untreated plots without tile drainage (parts per million)

Depth in feet	Carbonate CO_3	Bicarbonate HCO_3	Chloride Cl	Sulfate SO_4	Calcium Ca	Magnesium Mg	Sodium Na
		Before leaching (1929)					
0-1	0.0	152	22,603	3,730	4,302	1,505	8,703
1-2	.0	183	6,479	1,747	1,000	356	3,282
2-3	.0	214	4,189	1,378	494	229	2,454
3-4	.0	268	3,333	1,771	398	200	2,275
		After leaching (1931)					
0-1	.0	342	128	595	120	54	258
1-2	.0	299	224	1,262	122	60	610
2-3	18	317	344	1,603	92	70	888
3-4	24	378	586	2,376	108	70	1,424

The results of some additional investigations are given in the following reports.

Lands of the Colorado Delta in the Salton Sea Basin, by Frank J. Snow, E. W. Hilgard and G. W. Shaw, Bulletin No. 140, Agricultural Experiment Station, University of California, February 1902.

Soil Survey of the Imperial Area, California, by J. Garnett Holmes and party. Bureau of Soils, U. S. Dept. of Agriculture, 1903.

Irrigation in Imperial Valley, California, its Problems and Possibilities, by C. E. Tait, Irrigation Engineer, U. S. Dept. of Agriculture, Senate Doc. No. 246, 1st Sess., 60th Congress, February 1908.

Report of General Survey to Determine Cause and Extent of Water Logging in Imperial Valley, by Frank J. Veihmeyer and C. E. Tait. Irrigation Investigations, U. S. Dept. of Agriculture, 1914. (Typewritten.)

Report on Drainage Situation in Imperial Valley, California, by Walter W. Weir, Drainage Engineer, U. S. Dept. of Agriculture, April 1915. (Typewritten)

Investigation of Wells in Imperial Valley, by C. E. Tait and Wells A. Hutchins, Irrigation Investigations, U. S. Dept. of Agriculture and California State Dept. of Engineering, Bulletin No. 1, 1915.

Progress Report on Irrigation Requirements in Imperial Valley, California, by Frank J. Veihmeyer, Irrigation Investigations U. S. Dept. of Agriculture, 1917. (Typewritten)

Irrigation of Alfalfa in Imperial Valley, by Walter E. Packard, Bulletin No. 284, California Agricultural Experiment Station Sept. 1917.

Drainage Problems of Imperial Valley, California, by Walter W. Weir Agricultural Experiment Station, University of California, May 1919. (Mimeographed.)

Soil Survey of the El Centro Area, by A. T. Strahorn, E. B. Watson, A. E. Kocher, E. C. Eckmann, J. B. Hammon, Bureau of Soils, U. S. Dept. of Agriculture, 1922.

Soil Survey of the Brawley Area, California, by A. E. Kocher, E. J. Carpenter, W. C. Dean, Alfred Smith, S. W. Cosby, and M. E. Wank, Bureau of Soils, U. S. Dept. of Agriculture, 1923.

Silts in the Colorado River and its Relation to Irrigation, by Samuel Fortier and Harry F. Blanney, Division of Irrigation, U. S. Dept. of Agriculture, February 1928.

Investigations in Imperial and Coachella Valleys, California. (Economics, water supply, drainage, flood control and silt) By Paul A. Ewing, Harry F. Blaney, Walter W. Weir, J. H. McCormick, and Fred C. Scobey., U. S. Dept. of Agriculture, 1933. (Mimeographed)

Reclamation of White-Alkali Soils in the Imperial Valley, by Edward E. Thomas, University of California, Bulletin 601, 1936.

RECENT INVESTIGATIONS

For the 10 year period 1941 to 1951, the Soil Conservation Service, has been carrying on some type of leaching studies. While the main effort has been expended towards the development of tools and methods for the investigation and design of drainage systems the reclamation of these soils has also been part of the overall research work. In the early 1940's there was considerable impetus given by land owners to the growing of rice. It was hoped that by pending the water on the fine textured soils during the production of the rice crop that the saline elements would be driven down and out of the soils. At one time in 1942, about 14,000 acres of rice was planted, most of which was grown as a reclamation type crop. However, subsequent plantings of barley and other field crops indicated that only partial reclamation was accomplished and many of the fields soon became too saline for agricultural purposes. Some observational studies were made by the Imperial Irrigation District of the salt balance in these rice fields. The tests indicated that the saline elements were driven down to depths of 3 to 4 feet by the ponding of water for rice culture. However, when barley or flax was grown on these soils the saline elements would move up to the soil surface and production was unprofitable.

In 1943, some laboratory leaching studies were attempted using soils brought in from the Meloland Experimental Farm of the University of California. (3) These studies indicated that only a relatively small amount of water was required to pass completely through the soil profile to remove a large percentage of the saline elements.

In 1946, with the tremendous increase in tile installation in the valley there was a correspondingly great increase in the acreage of land being leached. The practice was to build contour borders in the fields and pond water to a depth of 9 to 18 inches for periods ranging from 30 days to 6 months or more. This practice appeared to be successful in most instances and is today the accepted method of reclaiming land in the valley. The questions raised by these practices were: (1) How long should the water be ponded on the various soils? (2) What are the best methods to use, keeping in mind that water should be conserved? (3) What are the costs and benefits of leaching?

These factors were the objectives of the subsequent leaching research. The studies which were carried on were conducted as the opportunity

presented itself and were not a rigid planned approach to the problem. Except for a few laboratory experiments and the Meloland Study, all the work was done on privately owned farms where control over the physical factors could not always be maintained.

LEACHING THEORIES

Before describing the reclamation research work it would be well to present some of the theories which are proposed as a guide to good leaching practice. These theories have been evolved from literature and reports on the movement of water through soils and from the field work carried on in Imperial Valley.

No. 1 When water is ponded over a tiled area there is more water flowing to the tile lines from areas adjacent to the lines than from points midway between laterals.

No. 2 When the ponded leaching water is removed, the ground water table allowed to recede and a draw-down curve obtained by the tile lines, the flow into the tile lines originates from all portions of the field. A s the draw-down curve falls more of the flow originates near the midpoint between laterals.

No. 3 When leaching is practiced by long periods of ponding, tile lines in coarse textured soil may become overloaded and back pressures may occur in the downstream reaches of the tile system. In some extreme cases impregnation of slaine elements may occur at these points.

No. 4 When the water is ponded the surface soil in leaching plots tends to deflocculate and segregate during a leaching period. In fine textured soils this may become quite a problem with respect to infiltration.

No. 5 When water is ponded salt may be added to the soil by the leaching water. Enough leaching water should be surface wasted during leaching of fine textured soils to maintain the salt balance in the leaching water.

No. 6 Leaching water will absorb or pick up considerable salt from the soil surface and on some slowly permeable soils the salt removal by the surface waste will approach that removed by the tile drainage system.

No. 7 Saline elements are removed from the surface soils to depth of 20 feet or more during leaching periods.

No. 8 Longer leaching periods are required, in fine textured soils, to remove the saline elements, to deeper depths.

ANALYSIS OF THEORIES

When examination is made of Theory No. 1, there are some interesting factors. Consider the hypothetical case: Water is ponded on the surface of the land which is drained by tile lines spaced an S distance apart. If the soil is homogeneous throughout and there is no barrier a draw-down curve will develop. If the tile lines are flowing full and there is no back pressure on the lines, the amount of flow in the laterals will originate in about the following proportions. About 50 percent of the flow will originate in the space S/8 on each side of the tile lines. The land on each side of the midpoint between tile lines will each produce about 5 percent of the flow. This theory, in principal, has been proven mathematically by Kirkham (5). Kirkham used a method of complex variables, image array and summation of velocity potential, stress line potential and drain flux.

The hypothetical case wherein the soil is homogeneous and there is no barrier to restrict streamline flow to the tile lines seldom exists in the field. When recognition is made of the probable presence of a barrier below the tile lines the flow becomes constricted and the flow from the midpoint becomes even less.

Theory No. 2 presents a diametrically opposite phenomenon. When ponded water is allowed to recede and a draw-down curve actually occurs about a tile line the flow to the tile line approaches equality from all the areas between the tile lines. As the pond disappears, the water in the soil over the tile line flows away producing a draw-down curve. When the curve falls to lower levels, the water originates all along the draw-down curve. If an equilibrium curve occurs, all the flow is originating near the midpoint between tile lines. This theory is important in that it suggests a procedure for leaching which would result in an equitable removal of saline elements throughout the entire reach between tile lines.

Theory No. 3 concerning the presence of back pressure in drainage systems during leaching periods is a critical factor in some soils. Back pressures have been observed in tile drainage systems during the time leaching was in progress. Back pressures on the Benson tile system, described in a previous report (2), were excessive and it was obvious that considerable amounts of saline elements were being deposited adjacent to tile laterals that were not being ponded. Studies on several tile drainage systems have indicated how excessive these back pressures can be. Back pressures in tile drainage systems generally occur where the collecting or base line is underdesigned in size for the permeability of the soil, the footage of tile installed, and the slope of the laterals and base-line.

Theory No. 4 has some basis for fact since there is evidence in practically all leaching ponds of deflocculation and segregation. Areas having fine textured soils show the greatest effect while soils of coarse

texture show only a trace on the surface. Fine textured soils may have a deflocculated layer of impervious material two inches thick and about one fifth the permeability of the soil immediately below it. The effect of this impervious layer can be minimized by using shorter leaching periods and by disturbing the soil surface with discs and chisels between leaching periods.

Theory No. 5 has greater significance in the fine textured soils. On soils having a very low permeability the evaporation from the ponds makes the leaching water relatively saline. Sufficient water should be routed through the ponds so that the saline concentration in the leaching water is low.

Theory No. 6 suggests that leaching water will absorb or pickup considerable salt from the soil surface if it is kept relatively fresh in the leaching plots. It is necessary to waste considerable water in order to counteract evaporation losses and maintain a salt balance in the leaching water.

Concerning Theory No. 7, it has been found that saline elements have been driven to depths greater than 20 feet during leaching runs. This phenomenon is of considerable value in reclaiming fine textured saline soils. It has been observed that initially the saline elements are pushed down below the root zone to depths considerably below the tile depth. It seems logical to suggest that some of these elements may be removed by the tile system over a long period of time as they slowly move back up to the surface.

Theory No. 8 maintains that saline elements are driven to deeper depths by long rather than short leaching periods in fine textured soils. A leaching period of 100 days on silty clay soils would remove a greater amount of salt to 20 feet than four 25 day periods. This is due to the extreme slowness of the percolation of the leaching water through the fine textured strata. It may require 40 days for an appreciable amount of leaching water to reach 15 or 20 feet in some soils. Thus if short term ponding periods are employed little if any deep movement of saline elements result. Some observations made in extremely fine textured soils indicated that after rice has been grown for 90 days the soils at a depth of 9 feet were still relatively dry.

EXPERIMENTAL LEACHING PROCEDURE

Experimental plots were selected at widely separated locations over the valley. The selected plots ranged from medium to highly saline concentrations and the soils ranged from moderately to slowly permeable. More emphasis was given to the study of fine textured, slowly permeable soils as they are the most difficult to reclaim and to maintain at a high productive level.

Selection of leaching sites

Leaching sites (excepting No. 1 Meloland) were selected on farms where a soil survey had been made by the Operations Division of the Soil Conservation Service and where a tile drainage system had been installed. The tile drainage systems on these tracts were designed by the Soil Conservation Service. Sites were selected where there were suitable drainage outlets. The investigations were set up in cooperation with the land owners.

Treatments and application of leaching water

No soil amendments such as lime, sulphur or gypsum were used on the soil or in the water applied on any of the field leaching studies. Ponding periods ranging in duration from 30 to 136 days were used in an effort to determine the most feasible and economical duration of leaching periods for various types of soils. The water applied was measured by submerged orifice gates (accurate within 10 percent) and by Parshall measuring flumes on the more intensive studies. The surface waste water was measured with Parshall flumes. Waste at the tile outlets was measured using the tile drainage effluent recorder. (1) An evapora tion pan was also installed on one of the leaching plots to determine the amount of water lost due to evaporation during leaching periods at various seasons of the year.

Soil sampling

Soil samples were obtained at each plot prior to leaching, at intervals during leaching, and following leaching operations. The four and five foot depth samples were taken with the Imperial Valley soil sampling equipment and the twenty foot depth samples were obtained with a 20 foot post hole auger. Soil samples were taken at various locations adjacent to and between the tile drainage laterals, and within the various soil classifications.

Crops following reclamation

On all test plots the soil was allowed to dry out and crack following the leaching. The highly saline leaching dikes were allowed to dry out so they could be worked. The dikes were leveled and the leached area plowed and the large clods worked down with a disc. The surface was then land-planed (or leveled) and bordered for irrigation. Barley was planted for the first crop following leaching. A crop of sesbania was planted as a cover crop for the summer season and the plots planted to alfalfa or grain the second year. Sesbania is an ideal first crop following leaching as it grows exceedingly well in the hot dessert climate. The irrigations during the sesbania crop also keep the remaining saline elements moving down rather than returning to the surface under capilary action. The sesbania also adds organic material to the soil which is a very important part of the reclamation.

Field experimental tract No. 1

This experimental tract was located at the University of California's Meloland Experimental Station on U. S. Highway 80, 5 miles east of El Centro, California. The plot consisted of 18 acres of land which had been tiled in 1939. A study of water applied and outflow from the tile system was maintained for 104 months from 1939 to 1948. This investigation was primarily a salt balance study. This study of input and outflow from a tile system was initiated in 1939 by the University of California in cooperation with the Imperial Irrigation District and the Roubidoux Laboratory of the U. S. Bureau of Plant Industry, at Riverside, California. In 1942 the Soil Conservation Service Research took over the work of measuring the tile effluent and the compilation of these data. After 104 months of observations this study was terminated in June of 1948.

The tile drainage system at Meloland Station consists of about 10,550 feet of four inch lateral lines and about 1, 969 feet of 6-inch collecting lines. The lateral lines are 5 to 6 feet below the ground surface and range in spacing from 80 to 400 feet. The soils are medium to slowly permeable to a depth of 10 to 12 feet. In 1939 a stilling box and V-notch weir together with a float and clock recorder were installed on the outlet of the collecting or base line to measure the drainage effluent.

Samples of the tile effluent were taken once a week. A composite was made of these samples and a complete analysis run once a month.

The water applied was measured with a submerged orifice headgate and delivered to the plots by an underground pipe system.

During the 104 months of operation, the tract of land on which the study was made was cropped to various experimental plantings. These plantings were all in small quarter and half acre plots. It was estimated that about 50% of the crop acreage, through the years, was in flax barley and wheat. There was no surface waste water during farming.

The plots leached were very small and water was ponded from 60 to 90 days on them. About 75 percent of the farm was leached during the 104 months.

Table 7 shows the total input irrigation and leaching water plus rainfall and outflow of waters on the tiled tract. The years of 1944-45-46 were years of heavy leaching and are indicated by the high drainage effluent percentage during those years. The last column in table 7 indicates that the drainage effluent percentage increased over a period of years. The average outflow over the nine years is 11 percent. A normal year's outflow, without leaching (1947) is 8.1 percent. This increase in percentage is probably due to small channels developing in the soils by percolation. These channels are very important since they increase drainability of the soil during normal irrigations and tend to improve the saline condition over a long period of time.

Table 7. Input and outflow of water for the years 1939 to 1948 on Tract No. 1 Meloland Tile Study, Imperial Valley, California. 1/

Year	Input			Outflow	Ratio
	Irrigation water 2/	Rainfall	Total input	Tile effluent	Percent discharge
	Acre-feet	Acre-feet	Acre-feet	Acre-feet	Percent
1939	25.01	0.00	25.01	0.96	3.8
1940	105.95	7.97	113.92	6.49	5.7
1941	84.68	22.25	106.93	6.52	6.1
1942	70.05	4.53	74.58	5.08	6.8
1943	54.41	11.56	65.97	4.54	6.9
1944	78.68	8.88	87.56	16.69	19.0
1945	82.06	7.36	89.42	18.58	20.8
1946	75.02	3.81	78.83	14.24	18.1
1947	75.76	.62	76.38	6.21	8.1
1948 4/	23.48	.00	23.48	2.41	9.4
Total	675.10	66.98	742.08	81.72	11.0

1/ The basic data from which tables 7 to 16 inclusive were compiled is in the files of the Imperial Irrigation District Testing Laboratory. Analysis of these data were made through the courtesy of the Imperial Irrigation District and The Meloland Experiment Station.
2/ Includes water applied for leaching purposes.
3/ Includes October, November, and December.
4/ Includes January to June inclusive.

Table 8 is a summary of the salt balance for the 104-month period of study. There was a net output of 312.82 tons of dissolved solids removed from this 18 acre tract during that period. This amounts to about 17.4 tons per acre removed from the tract. When consideration is taken of the fact that, had there been no tile system to remove these elements, about 36 tons of salts per acre would have been added to an already saline tract, the efficiency of the reclamation practices becomes increasingly apparent. While there was a 48 percent excess of total salts removed over the amount applied with the irrigation water, there was considerable base exchange. The calcium and bicarbonate were tied up releasing an excess of chlorides and sodium. The large increase in outflow over input of the nitrates may be attributed to the application of fertilizers on the various experimental plots.

Table 8. Salt balance, for period October 1939 to June 1948, Tract No. 1 Meloland, Tile Study, Imperial Valley, California.

Chemical elements		Total input	Total discharge	Elements removed
		Tons	Tons	Percent
Dissolved Solids		652.90	965.72	148.0
Calcium	(Ca)	86.12	69.94	81.1
Magnesium	(Mg)	25.91	38.09	147.0
Sodium	(Na)	84.18	185.65	220.8
Bicarbonate	(HCO_3)	74.73	21.39	28.6
Sulphate	(SO_4)	275.03	283.77	103.0
Chloride	(Cl)	75.96	276.78	364.5
Nitrate	(NO_3)	1.54	11.37	737.0

Table 9 shows a comparison between input and outflow of total dissolved solids by years. This table reveals three significant factors that play an important part in the reclamation and the maintainance of a favorable salt balance in fine textured soils.

1. Some years the total outflow of saline elements is less than the input.

2. The rate of outflow of saline elements per acre foot of tile effluent has varied only slightly through the nine years.

Table 9. Input and outflow of total dissolved solids, by years, Tract No. 1 Meloland Tile Study, Imperial Valley, California, 1939 to 1948.

Year	Input: Dissolved solids	Outflow: Dissolved solids	Ratio: Percent removed	Rate of removal per acre foot of tile effluent
	Tons	Tons	Percent	Tons/acre ft.
1939 1/	27.10	11.21	41.4	11.68
1940	121.90	66.87	54.9	10.30
1941	67.96	71.38	105.0	10.95
1942	71.40	56.38	79.0	11.10
1943	41.15	46.61	113.3	10.27
1944	66.66	212.73	319.1	12.75
1945	77.99	231.10	296.3	12.44
1946	76.70	180.30	235.1	12.66
1947	78.14	66.95	85.7	10.78
1948 2/	23.90	22.19	92.8	9.21
Total or average	652.90	965.72	148.0	11.82

1/ Includes October, November, and December.
2/ Includes January to June inclusive.

Table 10. Input and outflow of calcium, by years, Tract No. 1 Meloland Tile Study, Imperial Valley, California.

Year	Input: Dissolved solids	Outflow: Dissolved solids	Ratio: Percent removed	Rate of removal per acre foot of tile effluent
	Tons	Tons	Percent	Tons/acre ft.
1939 1/	3.70	0.77	20.8	0.80
1940	15.56	4.63	29.8	.71
1941	8.52	5.13	60.2	.79
1942	8.89	4.18	47.0	.82
1943	5.49	3.38	61.6	.74
1944	8.60	15.92	185.5	.95
1945	10.67	16.53	154.9	.89
1946	10.32	12.74	123.5	.89
1947	11.07	5.02	45.4	.81
1948 2/	3.30	1.64	49.7	.68
Total or average	86.12	69.94	81.1	0.86

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

3. The years when there was an excess of outflow of saline elements over input were those years when leaching was practiced on some of the plots.

These factors support the proposals that saline elements may be built up in a fine textured soil profile over a period of years in land served by tile drainage and require additional leaching periods; and that saline elements may be carried to a deeper depth below the tile lines and slowly return towards the surface to be removed by the tile drainage system.

Tables 10 through 16 inclusive show a comparison between input and outflow by years of the various chemical elements found in the water samples. The analysis of these data indicates an almost uniform rate of withdrawal of the various chemical elements. The rate in almost every case increased slightly during the leaching periods.

The following conclusions have been made from this salt balance study:

1. Drainage from properly maintained tile systems apparently improves with age and can be expected to increase in efficiency. This increase in efficiency helps reduce the frequency of leaching.

2. The volume of outflow from a tile system approaches 10 percent of the input from irrigations and rainfall over a 9 year period. The outflow percentage at the time of tiling was 3.8% and at the close of the study it had increased to 9.4 percent.

3. The tile drainage system has been very successful in reclaiming this tract.

4. The real success of the drainage system in terms of salts removed revolves about the leaching program.

5. There is little or no increase or decrease in the rate of removal of saline elements by a tile drainage system over a period of years. This may be due to the fact that saline elements are continually moving up from deeper strata.

Field experimental tract No. 2

This experimental tract was located south east of Holtville, California on the O'Dwyer-Mets farm. The observations of the salinity trend of the tile drainage effluent were made over an 80 day leaching period. The soils are of medium permeability to a depth of nine feet. The tile drainage system was installed in 1945. The system consists of 10,560 feet of four inch lateral lines and about 1270 feet of 6-inch collecting lines. The lateral lines are 5½ feet below the ground surface and range in spacing from 160 to 300 feet.

Table 11. Input and outflow of magnesium, by years, Tract No. 1 Meloland Tile Study, Imperial Valley, California.

Year	Input	Outflow	Ratio	Rate of removal per acre foot of tile effluent
	Dissolved solids	Dissolved solids	Percent removed	
	Tons	Tons	Percent	Tons/acre ft.
1939 1/	0.92	0.47	51.5	0.49
1940	4.26	2.68	62.9	.41
1941	2.30	2.84	123.5	.44
1942	2.84	2.11	86.8	.42
1943	1.49	2.03	136.2	.45
1944	2.71	8.28	305.5	.50
1945	3.58	9.05	252.8	.49
1946	3.57	7.12	198.9	.50
1947	3.60	2.67	74.2	.43
1948 2/	1.04	.83	79.8	.34
Total or average	25.91	38.08	147.0	0.47

Table 12. Input and outflow of sodium, by years, Tract No. 1 Meloland Tile Study, Imperial Valley, California.

Year	Input	Outflow	Ratio	Rate of removal per acre foot of tile effluent
	Dissolved solids	Dissolved solids	Percent removed	
	Tons	Tons	Percent	Tons/acre ft.
1939 1/	3.50	2.29	65.5	2.39
1940	15.91	13.31	83.6	20.5
1941	9.53	14.34	150.5	2.20
1942	9.35	11.00	117.6	2.17
1943	5.54	9.17	165.5	2.02
1944	9.60	41.54	432.7	2.49
1945	8.64	44.70	517.4	2.41
1946	9.48	33.11	349.3	2.33
1947	9.79	12.28	125.4	1.98
1948 2/	2.84	3.91	137.7	1.62
Total or average	84.18	185.65	220.8	2.27

1/ Includes October, November, and December.
2/ Includes January to June inclusive.

Table 13. Input and outflow of bicarbonate, by years, Tract No. 1 Meloland Tile Study, Imperial Valley, California.

Year	Input	Outflow	Ratio	Rate of removal per acre foot of tile effluent
	Dissolved solids	Dissolved solids	Percent removed	
	Tons	Tons	Percent	Tons/acre ft.
1939 1/	2.65	0.34	8.4	0.35
1940	11.17	1.34	12.0	.21
1941	6.50	1.65	25.4	.25
1942	7.04	1.36	19.3	.27
1943	4.58	.97	21.2	.21
1944	7.80	4.21	54.0	.25
1945	8.56	4.74	55.4	.26
1946	8.39	4.15	49.5	.29
1947	15.25	1.99	13.1	.32
1948 2/	2.79	.74	26.5	.31
Total or average	74.73	21.49	28.6	0.26

Table 14. Input and outflow of sulphate, by years, Tract No. 1 Meloland Tile Study, Imperial Valley, California.

Year	Input	Outflow	Ratio	Rate of removal per acre foot of tile effluent
	Dissolved solids	Dissolved solids	Percent removed	
	Tons	Tons	Percent	Tons/acre ft.
1939 1/	11.82	3.70	31.3	3.85
1940	52.56	20.29	38.6	3.13
1941	27.60	13.51	48.9	2.07
1942	30.10	18.25	60.6	3.59
1943	17.94	15.33	85.5	3.38
1944	29.22	64.29	220.0	3.85
1945	30.52	68.07	223.0	3.66
1946	32.33	51.22	158.4	3.60
1947	33.29	21.67	65.1	3.49
1948 2/	9.65	7.44	77.1	3.09
Total or average	275.03	283.77	103.0	3.47

1/ Includes October, November, and December.
2/ Includes January to June inclusive.

Table 15. Input and outflow of chloride, by years, Tract No. 1 Meloland Tile Study, Imperial Valley, California.

Year	Input	Outflow	Ratio	Rate of removal per acre foot of tile effluent
	Dissolved solids	Dissolved solids	Percent removed	
	Tons	Tons	Percent	Tons/acre ft.
1939 1/	2.89	3.25	112.5	3.39
1940	13.22	19.56	148.0	3.01
1941	8.45	20.80	246.2	2.19
1942	7.28	15.04	206.5	2.96
1943	4.21	12.59	299.1	2.77
1944	7.50	63.05	840.7	3.78
1945	9.68	67.42	696.5	3.63
1946	9.68	51.86	535.7	3.64
1947	10.12	17.35	171.4	2.79
1948 2/	2.93	5.86	200.0	2.43
Total or average	75.96	276.78	364.5	3.39

Table 16. Input and outflow of nitrate, by years, Tract No. 1 Meloland Tile Study, Imperial Valley, California.

Year	Dissolved solids	Dissolved solids	Percent removed	Rate of removal per acre foot of tile effluent
	Tons	Tons	Percent	Tons/acre ft.
1939 1/	0.04	0.14	346.0	0.15
1940	.23	1.15	500.0	.19
1941	.19	.94	494.7	.14
1942	.18	.71	394.4	.14
1943	.10	.57	570.0	.13
1944	.15	2.47	1,646.7	.15
1945	.16	4.00	2,500.0	.22
1946	.21	.94	447.6	.07
1947	.21	.36	171.4	.06
1948 2/	.07	.09	128.6	.04
Total or average	1.54	11.37	737.0	0.14

1/ Includes October, November, and December.
2/ Includes January to June inclusive.

[illegible]

Samples of the tile effluent were taken weekly and analyzed for chlorides and total salts. Table 17 shows the salinity changes in the tile effluent over an 80 day leaching period. The percentage reduction in saline content of the drainage effluent is more marked in the chlorides than the total salts. This is due to the greater solubility of the chlorides over the other salts.

Field experimental tract No. 3

This experimental tract was located on 80 acres of the H. B. Ross farm south east of Holtville, California. Observations on the salinity trend of the tile drainage effluent were made prior to, during, and following a 62 day leaching period. The soils range from readily to slowly permeable to a depth of 9 feet and have an overall permeability rating of 33 gallons per square foot per day. The tile drainage system was installed during July of 1947. This system consists of 14,700 feet of 4-inch lateral lines and 1350 feet of 6-inch and 800 feet of 8-inch collecting lines. The lateral lines are 5.5 feet below ground surface and are spaced at 300 feet.

Samples of the tile effluent were taken weekly and analysis was made for chlorides and total salts. Table 18 shows the salinity fluctuations of the tile drainage effluent during the leaching investigation. The concentration of total salts and chlorides gradually decreased during the leaching period, however, the concentration of salts in the drainage effluent returned to within about 80 percent of normal following the leaching period.

Field experimental tract No. 4

This tract was located on 60 acres of the W. B. Collins ranch north west of Westmorland, California. Observations on the tile effluent salinity were made in conjunction with the movement of saline elements in the top five foot soil profile during two 30 day leaching periods. Soil samples were taken at two locations in the field to determine this movement of saline elements. The soils at the sample locations has a medium surface texture, were moderately to slowly permeable from 1 to 5 feet and moderate to rapidly permeable from 5 to 9 feet.

The tile drainage system was installed in February of 1949. It consists of 4,683 feet of 4 inch lateral lines and 2,448 feet of 6-inch collecting line. The lateral lines are 5.5 feet below the ground surface and are spaced at 300 feet.

On March 30, 1949, before water was ponded on the leach plot, soil samples to a depth of 5 feet were obtained at two sites. Leaching water was ponded on the land for 30 days during the month of April. The ponds

Table 17. Salinity data, O'Dwyer - Mets farm Tract No. 2, Imperial Valley, California

Time of sampling	Depth of water removed by the tiled drainage system	Average total salt content of the tile drainage effluent	Accumulated total salt removed by the drainage system per acre	Average chloride content of the tile drainage effluent	Accumulated chlorides removed by the drainage system per acre
	Feet	Tons/ac.ft.	Tons	Tons/ac.ft.	Tons
Started leaching August 18, 1946	0	15.30	0	3.60	0
End of 10 days	0.031	12.65	0.37	3.30	0.08
End of 20 days	0.119	11.75	1.27	2.90	0.35
End of 30 days	0.198	10.50	2.07	2.60	0.57
End of 40 days	0.287	9.85	2.88	2.20	0.76
End of 50 days	0.370	9.30	3.61	2.00	0.95
End of 60 days	0.449	9.10	4.10	2.10	1.07
End of 70 days	0.498	9.05	4.46	1.90	1.16
End of 80 days	0.589	9.00	5.09	1.80	1.31

Table 18. Salinity data, Ross farm Tract No. 3, Imperial Valley, California

Date	Tile drainage discharge	Accumulative tile drainage discharge per acre	Average total salt content of the tile drainage effluent	Accumulated total salt removed by the drainage system per acre	Average chloride content of the tile drainage effluent	Accumulated chlorides removed by the drainage system per acre	Remarks
	G.P.M.	Ac. ft.	Tons/ac.ft.	Tons	Tons/ac.ft.	Tons	
Pre leaching period							
6-27-47	50		22.1		8.9		
7-4-47			24.7		7.6		
7-11-47			17.6		6.7		
7-18-47			20.8		7.6		
7-25-47	27		19.2		7.8		
Leaching started 7/27/47							7/27 water on
8-1-47	80	0.011	15.0	0.168	5.4	0.067	
8-8-47	150	0.034	16.1	0.512	6.3	0.202	
8-15-47	286	0.079	17.0	1.212	6.3	0.481	
8-22-47	345	0.144	16.4	2.228	5.7	0.862	
8-29-47	320	0.213	15.6	3.249	5.3	1.230	
9-5-47	320	0.279	11.6	4.072	5.0	1.560	
9-12-47	320	0.345	13.8	4.837	5.0	1.880	
9-19-47	187	0.397	15.9	5.553	5.5	2.147	
9-26-47	120	0.429	16.9	6.039	6.0	2.325	9/26 water off
Post leaching period		0.448	17.5	6.377	6.4	2.447	
10-3-47	70	0.460	18.0	6.579	6.9	2.522	
10-10-47	40	0.467	18.6	6.704	7.1	2.570	
10-17-47	25						

were allowed to dry and a second set of soil samples were taken on May 18, 1949. A second ponding of 30 days was then made during May and June of 1949. After the second leaching the land was allowed to dry out and a third set of soil samples were taken on July 19, 1949.

A summary of the saline movement in the top 5 foot soil profile is given in table 19.

Experimental tract No. 5

This tract was located on 52 acres of the Simons ranch north east of Westmorland, California. Observations on the tile effluent salinity were made in conjunction with the movement of saline elements in the top 4 foot soil profile during leaching. The soil had a light to medium surface texture and was moderately permeable to a depth of 9 feet.

The ranch was tiled at a 600 foot spacing and leached with a rice crop in 1940. In 1947 additional tile lines were installed making the spacing 300 feet and the plot was leached for 84 days. Samples of soil were taken to a depth of 4 feet and composites were analyzed for total dissolved salts, calcium, magnesium, sodium, carbonate and bicarbonate, sulfate, chloride and nitrate. A tile effluent recorder, placed on the tile outlet, recorded flow from the tile lines and periodic sampling of this flow was made. A total of 22 tons of salt per acre were removed by the tile drains during the leaching and it is calculated that a total of approximately 0.3 acre feet per acre of water percolated through to the drains and out the tile drainage system. There were no signs of any diminution of salt content in the leach water at the end of the 84 days. This would indicate that a satisfactory leaching of the soil had not been effected at the time the leaching was terminated. This fact was substanciated by the poor crops that were grown on the reclaimed area. Table 20 details the laboratory analysis of soil samples from the Simon plot taken before and after leaching. Note that while the top two feet was leached of a considerable amount of saline content, the third and fourth foot show almost no change.

Field experimental tract No. 6

This tract was located on 240 acres of the Immel ranch, north east of Holtville. Observations of the salinity trend of the tile drainage effluent were made in conjunction with the movement of saline elements in the top 5 foot soil profile during 129 days of continuous leaching. The soil had a medium surface texture and was moderately permeable to a depth of 9 feet.

The tile drainage system was installed in May of 1947. It consists of 16,730 feet of four inch lateral lines, 2585 feet of interception line and 4623 of 6-inch and 1600 feet of 8-inch collecting line. The tile is installed at a depth of 6 feet below the ground surface and the lateral are spaced at 250 foot intervals.

Table 19. Concentration of total dissolved solids in soil samples from Collins ranch, Tract No. 4, Imperial Valley, California.

Depth of sample	Before leaching total solids		After 30 days leaching total solids		After 60 days leaching total solids	
Feet	P.p.m.	T.a.f.	P.p.m.	T.a.f.	P.p.m.	T.a.f.
			Plot A			
0-1	5,350	18.70	4,010	8.02	2,110	4.22
1-2	9,030	18.06	6,560	13.12	5,060	10.12
2-3	6,010	12.02	5,370	10.74	5,540	11.08
3-4	4,480	8.96	2,550	5.10	2,050	4.10
4-5	3,180	6.36	2,180	4.36	3,040	6.08
			Plot B			
0-1	7,150	14.30	6,780	13.56	5,490	10.98
1-2	10,630	21.26	8,220	16.44	7,610	15.22
2-3	8.800	17.60	8,540	17.08	7,190	14.38
3-4	6,500	13.00	4,560	9.12	4,380	8.76
4-5	6,740	13.48	5,410	10.82	4,490	8.98

P.p.m. = Parts per million
T.a.f. = Tons per acre-foot of water

Table 20. Chemical analysis of soil samples from the Tract No. 5, Simons Ranch, Imperial Valley, California

Depth ft.	Cond. $K \times 10^5$ 25°	T.D.S. T. ac. ft.	T.D.S. p.p.m.	Calcium	Magnesium	Sodium	Carbonate and bicarbonate	Sulfate	Chloride	Nitrate
BEFORE LEACHING										
						Milli equivalents per liter on dry wt. of soil				
1	635	46.28		128.5	68.6	134.8	00 + 9.00	82.5	240	0.35
2	356	27.88		72.25	32.4	97.0	00 + 5.00	121.5	75	.20
3	302	19.22		30.00	20.3	105.8	00 + 5.00	60.9	90	.15
4	354	21.70		19.70	20.5	128.6	00 + 5.00	28.6	135	.20
						Parts per million				
1			23,140	2,570	837	3,100	549	3,960	8,520	22
2			13,940	1,445	395	2,910	305	5,832	2,663	12
3			9,610	600	248	3,174	305	2,926	3,195	9
4			10,850	394	249	3,858	305	1,373	4,793	12
AFTER LEACHING										
						Milli equivalents per liter on dry wt. of soil				
1	172	12.84		38.50	3.95	54.05	00 + 7.00	69.50	20.00	
2	259	18.58		50.00	3.95	81.05	00 + 4.00	91.00	40.00	
3	303	19.14		27.50	5.20	122.30	00 + 4.50	45.50	105.00	
4	330	21.22		32.50	6.80	122.95	00 + 3.50	43.75	115.00	
						Parts per million				
1			6,420	770	48	1,243	427	3,336	710	
2			9,290	1,000	48	1,864	244	4,368	1,420	
3			9,570	550	63	2,813	275	2,184	3,728	
4			10,610	650	72	2,828	218	2,100	4,083	

1/ I. I. D. Laboratory, R. B. Trexler, Analyst, August 11, 1947.

A Bradshaw type flow recorder (1) was used to measure the drainage effluent. Samples of the effluent were collected and analyzed weekly. A total of about 53 tons of dissolved salts per acre were removed by the drainage system during this study and it is calculated that a total of approximately 0.70 acre feet per acre of water percolated through the soil to the drains and out the tile system. Here again there was no sign of diminution in the saline content of the leach water at the end of the study. Table 21 details the laboratory analysis of the composite soil samples that were taken to a depth of five feet in the plot. In this instance, the post leaching samples revealed a large decrease in the salt content of the lower two feet; the third foot appears to have remained static. This change is apparent in some of the other elements analyzed particularly magnesium and chloride.

Field experimental tract No. 7

The investigations on this tract were the most comprehensive field studies of leaching attempted by the project staff. A farm plan was written by the Soil Conservation Service, Operations staff in the fall of 1948. It called for the tiling and leaching of a 160-acre tract of land north west of Holtville. This tract was tiled on a 337-foot spacing early in 1949 and prepared for leaching by the construction of contour borders. Preparatory to carrying on water measurements, the following recording devices were installed: A wood Parshall flume with a one-foot width throat was installed at the inlet to the field to record the amount of water applied. A type-L, water-stage recorder was used to obtain a continuous flow check of water depth in the flume. A similar device was installed at the surface-waste outlet at the lower edge of the field.

A Bradshaw-type (1) tile flow recorder was installed on the tile outlet to secure a continous record of the tile drainage effluent. A Young-type screen evaporation pan was installed near the north edge of the field about 100 feet inside the leaching area. This pan was installed to record evaporation during the leaching trials. Several batteries of piezometers were installed adjacent to and out from the tile lines near the middle of the field.

Figure 3 is a map of the Wilson leaching tract showing the drainage system layout, location of the measuring devices used and the soil sampling station locations used during the study. A soil sampling station was located in the corners of the field, and one row of stations was established in a line at right angles to the lateral tile system in the center of the field. Two 20 foot sample stations were located and soil samples at one-foot increments were obtained before leaching began. All the other sites were sampled to a depth of five feet in one-foot increments. A total of 410 soil samples were taken during the study and an analysis was made of these in the laboratory. The procedure in making the study was to pond water on the surface to an average depth of about one foot for 30 to 136 day periods.

Table 21. Chemical analysis of soil samples from the Tract No. 6, Immel Ranch, Imperial Valley, California. 1/

Depth ft.	Cond. K x 10^5 25°	T. D. S. T. ac. ft.	T. D. S. p. p. m.	Calcium	Magnesium	Sodium	Carbonate and bicarbonate	Sulfate	Chloride
				BEFORE LEACHING					
					Milli equivalents per liter on dry wt. of soil				
1	1298	95.00		185.00	73.00	442.6	00 + 6.10	194.5	500.0
2	799	56.62		90.00	38.75	304.7	00 + 5.00	188.5	240.0
3	518	37.42		78.00	23.30	183.2	00 + 8.50	151.0	125.0
4	386	27.14		39.50	19.20	148.0	00 + 4.00	105.0	97.5
5	316	20.88		18.00	6.65	123.0	00 + 5.00	69.7	72.5
						Parts per million			
1			47,500	3,700	890	10,180	372	9,336	17,750
2			28,310	1,800	473	7,009	305	9,048	8,520
3			18,710	1,560	284	4,213	519	7,248	4,438
4			13.570	790	234	3,399	244	5,040	3,461
5			10,440	360	81	1,495	305	3,346	2,574
				AFTER LEACHING					
					Milli equivalents per liter on dry wt. of soil				
1	210	16.90		42.50	17.90	70.10	00 + 6.50	99.50	25.00
2	438	32.88		59.50	22.25	154.75	00 + 4.50	159.50	72.50
3	585	41.68		78.50	25.70	202.70	00 + 3.00	156.50	147.50
4	715	49.00		74.50	42.30	252.70	00 + 3.00	136.50	230.00
5	596	37.96		45.00	28.30	225.70	00 + 3.00	86.00	210.00
						Parts per million			
1			8,450	850	218	1,612	394	4,752	888
2			16,440	1,190	271	3,559	275	7,656	2,574
3			20,840	1,570	313	4,662	183	7,512	5,236
4			24,500	1,490	517	5,812	183	6,552	8,165
5			18,980	900	345	5,191	183	4,128	7,455

1/ I. I. Laboratory, R. B. Trexler, Analyst, December 13, 1947.

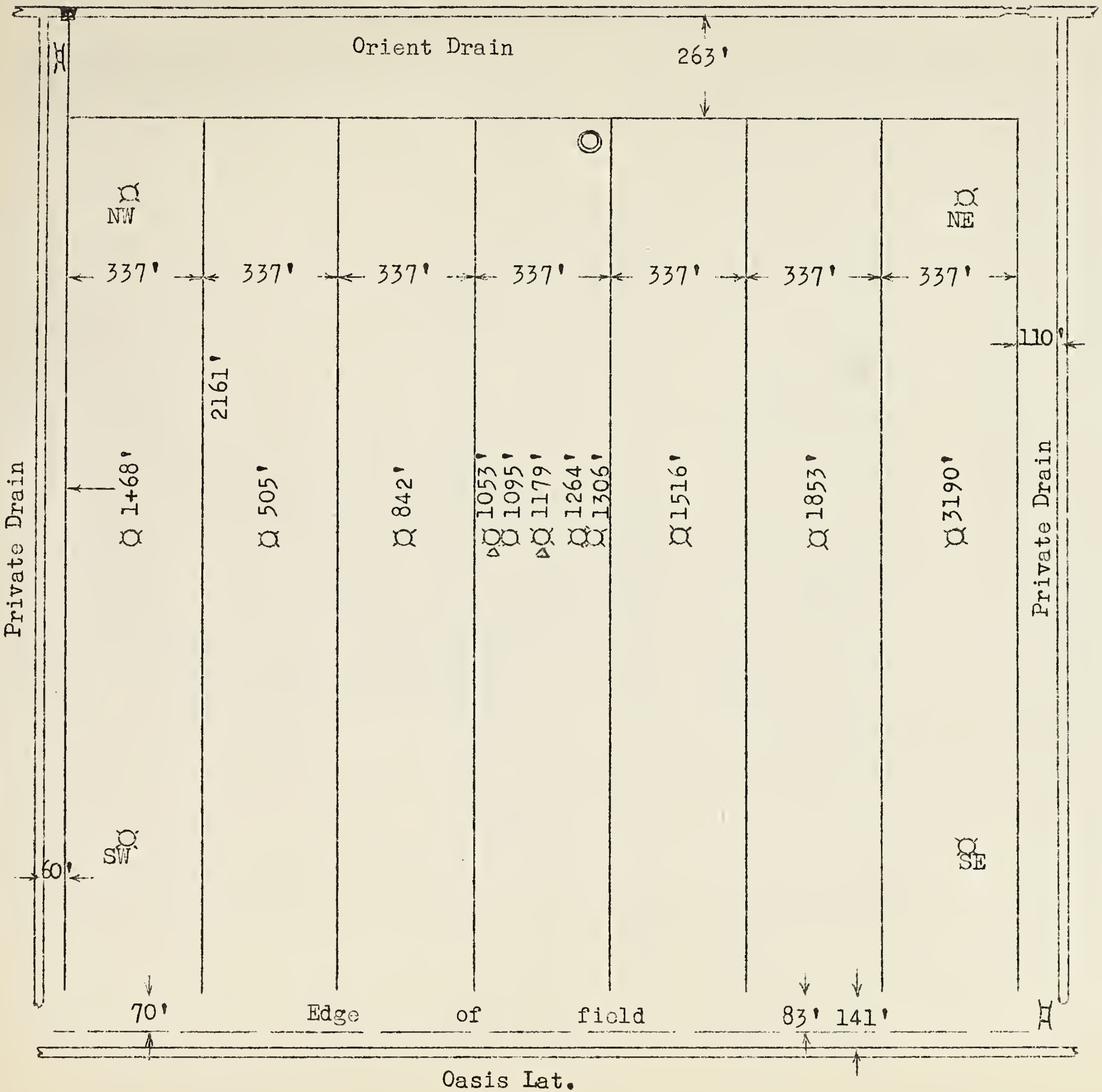


Figure 3. Wilson's Leaching Study Tile drainage system, soil sample locations, piezometer locations, evaporation pan locations, and water measuring locations.

Installed tile
Soil sample locations
Piezometer locations
Parshall measuring flumes
Tile effluent recorder
Evaporation pan

After each ponding period, the field was allowed to dry up and a set of soil samples was taken. Samples of inflow, outflow, tile effluent and evaporation pan readings were taken once a week and analysis made of the saline content. Figure 4 depicts the soils on the leaching tract. They are predominately slow to moderately permeable and have an over-all prorated permeability of 3.1 gallons per square foot per day. This is an extremely low permeability for drainage work and makes reclamation a lengthy process.

Analysis of Data

Table 22 is a summary of the five leaching runs made on the Wilson ranch. The first run was a 30-day leaching period. The second run a 46-day, the third run a 74 days, and the fourth a 48-day and the fifth was a 136-day leaching period. The most significant features of comparison of these five runs are the following:

Waste water

There was considerable waste of water during the leaching trials. This may be attributed in part to the fact that in leaching heavy textured soils the water passes very slowly through the soil to the drain and only a small percentage reaches the tile lines. The balance of the leach water is either wasted or evaporated from the ponds. Table 23 gives some details on the surface waste, the amount wasted, percentage of water wasted and the tons of salt removed or deposited by the leaching water moving over the field.

Table 23. Surface waste water and surface movement of saline elements from Tract No. 7 Wilson leaching plot. Imperial Valley, California.

Leaching trial	Duration	Water wasted	Percent wasted 1/	Movement of saline elements by waste water 2/
	Days	Ac. ft.	Percent	Tons
1st	30	63	33.5	-137
2nd	46	224	56.9	-359
3rd	74	553	66.9	-322
4th	48	337	80.6	-144
5th	136	506	44.5	⨍347

1/ Percentage of the amount applied.
2/ - removed from field. ⨍ added to field.

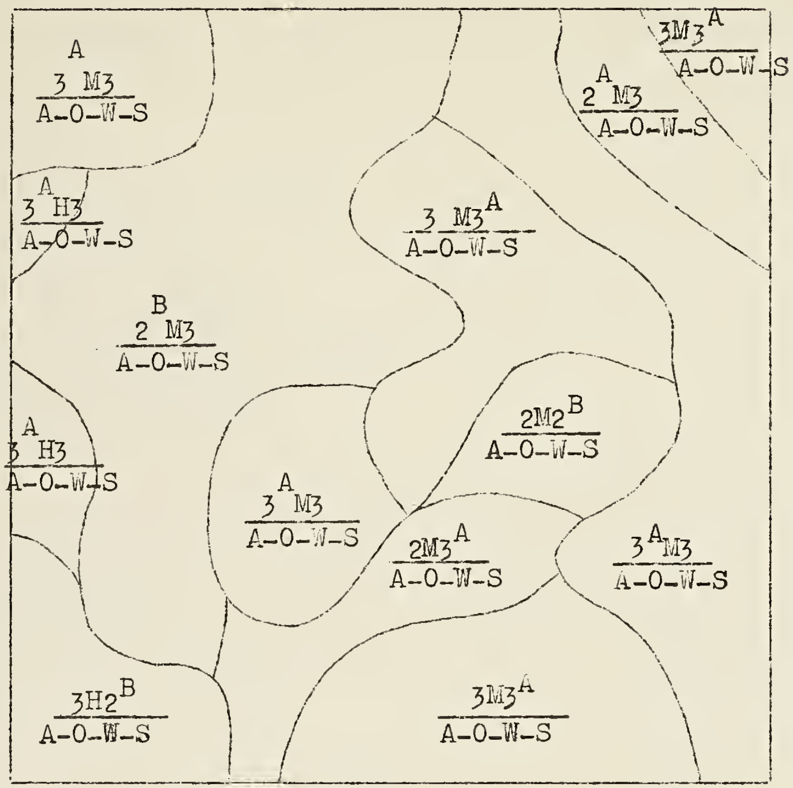


Figure 4. Wilson's leaching study soils map.

A - The slope is less than one foot per 100 feet
O - No apparent erosion
W - Water table within depth of survey
S - Salts concentrated on or near the surface in sufficient density to prevent growth of crops.

Soils map from cooperative farm plan No. 65 with the Imperial Irrigation District prepared by the Soil Conservation Service.

B
2 M3

M - Texture of surface foot
2 - First number is permeability index of one to five feet
3 - Last number is permeability index of five to nine feet
M - Medium surface texture
H - Heavy surface testure
2 - Moderately permeable
3 - Slowly permeable

An "A" superscript indicates there are one or more minor lenses of more permeable material within that portion of the soil profile

A "B" superscript indicates there are one or more minor lenses of less permeable material within that portion of the soil profile.

Table 22. Summary of five leaching tests on the Tract No. 7, Wilson Plot, Imperial Valley, California.

Item	Units	First run	Second run	Third run	Fourth run	Fifth run
		Dates	Dates	Dates	Dates	Dates
Water applied		3-3-49	5-15-49	7-19-49	12-26-49	4-18-50
Water turned off		4-1-49	6-30-49	10-1-49	2-11-50	8-31-50
Surface waste started flowing		3-14-49	5-26-49	7-29-49	1-6-50	5-9-50
Surface waste stopped flowing		4-15-49	7-2-49	10-9-49	2-18-50	9-19-50
Tile discharge increase		3-4-49	5-18-49	7-21-49	12-28-49	4-20-50
Tile discharge to normal		5-12-50	7-21-49	11-30-49	4-2-50	10-14-50
Peak tile discharge occurred		4-1-49	6-25-49	8-7-49	1-1-50	7-27-50
Peak saline concentration occurred		4-29-49	6-3-49	8-12-49	3-31-50	4-21-50
Preleaching soil sampling		3-1-49	5-6-49	7-18-49	12-2-49	4-13-50
Postleaching soil sampling		5-6-49	7-18-49	12-2-49	4-13-50	10-31-50
	Units	Results	Results	Results	Results	Results
Net area leached	Acres	140	140	140	140	140
Duration of leaching	Days	30	46	74	48	136
Total water applied	Acre feet	188	394	827	418	1136
Total salts applied in water	Tons	243	493	1254	589	1610
Total water surface wasted	Acre feet	63	224	553	337	506
Total salts surface wasted	Tons	380	852	1576	733	1263
Total water from tile system	Acre feet	14.1	13.8	24.6	14.9	45.2
Total salts removed by tile system	Tons	858	864	1288	686	1463
Average daily tile flow	Acre feet	0.47	0.31	0.33	0.31	0.33
Rate of salt removed per day by tile system	Tons	28.6	18.8	17.4	14.3	10.8
Peak tile discharge	G. P.M.	79	86	73	49	86
Peak saline concentration of effluent	T. A. F.	66	68	55	49	49
Total net salts removed from plot	Tons	895	1224	1609	830	1115
Net salts removed per acre	Tons	6.4	8.7	11.5	5.9	8.0
Net salts removed per acre foot of water used	Tons	4.7	3.1	1.9	2.0	1.0
Total evaporation from plot	Acre feet	103	147	229	55	554
Water computed to deep seepage	Acre feet	8	9	20	11	31
Evaporation per day	Acre feet	3.4	3.4	3.1	1.2	4.1

This tabulation substanciates theory No. 6 in that salt is picked up by the leaching water, as it moves over the leach plots, and is removed by the surface waste water. On heavy saline soils requiring drainage, the surface often becomes highly saline, sometimes several hundred tons of salt per acre foot. The first waste water flushed over the soil picks up some of the salt. This is shown in the 1st leaching run where 137 tons of salt was removed by 34 percent of the water applied.

As the leaching progresses the surface soil becomes less saline and there is less salt for the surface water to absorb. This is shown by the decreasing amount of salt being removed by the waste water in the subsequent leaching runs. The tabulation also indicates that on each succeeding leaching trial the percentage wasted had to be increased in order to show some removal by the waste water. On the fifth leaching run the waste was cut to 44% which was too low. On this last run 347 tons of salt were added to the 140 acre experimental plot. This could have been prevented if the leaching water had been kept fresher by maintaining a higher percentage of surface waste.

Evaporation

There was a large amount of evaporation from the surface of the leaching ponds. This is the first time that checks have been made of evaporation rates adjacent to a leaching plot. Table No. 24, gives the acre feet of water evaporated for each ponding period and the average acre feet lost per day over the entire 160 acres being leached.

Table 24. Surface evaporation on Tract No. 7 Wilson's leaching plot, Imperial Valley, California. 1/

Item	Leaching Periods				
	1st	2nd	3rd	4th	5th
Dates leached	Mar.-Apr.	May-June	July-Oct.	Dec.-Feb.	Apr.-Aug.
Total evaporation inches	8.83	12.60	19.62	4.71	47.48
Total acre feet evaporated from tract	1.03	147	229	55	554
Acre foot evaporated per day	3.4	3.4	3.1	1.2	4.1

1/ The evaporation has been reduced to lake conditions from Art Young screen pan data.

As can be expected, the periods of high evaporation are during the summer months and the periods of lower evaporation occur during the winter. Evaporation plays an important part in leaching as most of the leaching in Imperial Valley is done during the semi-dormant summer months.

Salts removed

There was a small net amount of dissolved solids removed per acre foot of water used. Indications are that the net salts removed per acre-foot of water used dwindles with succeeding trials. The amount of saline elements removed per foot of water applied was as follows: first trial, 4.7 tons; second trial 3.1 tons; third trial, 1.9 tons; fourth trial, 2.0 tons and fifth trial, 1.0 tons. This decrease is probably due to a reduction of mineral elements in the surface soil and a reduction in the immediate vicinity of the tile drainage laterals.

A study was also made of the movement of saline elements with respect to proximity to the tile lines. Table 25 is a compilation of data from the soil sampling at sites adjacent to the tile lines and at various other sites ranging to midway between the tile drainage laterals. The removal of saline elements from the midpoints between the tile lines was slight during the first leaching trial. The results shown in the table tend to substanciate theory No. 1, which states that there is more water flowing to the tile lines from areas adjacent to the tile linesthan from points midway between tile laterals. There also appears to be an increase in the percentage of saline content of the soil at the five foot level over the original content before leaching at nearly all stations. During the fourth and the long fifth run the salinity near the midpoint between the tile lines was greatly reduced. Table No. 26 gives the conductance on a five to one soil solution, and the tons of salt per acre foot of soil, for the five leaching runs. The tons of salt per acre foot values range from 1.5 to 76.6 with an average of about 27 tons in the surface foot. This is a relatively high concentration for crop growth. The estimated 60 to 70 percent plant coverage for the barley crop following leaching indicate that the concentration is too high. The 20 foot soil sample analysis from table 26 have been plotted and shown in Figure 5. Station 10 + 28 was located adjacent to the tile line and station 11 + 79 was located midway between two tile laterals. Figure 5 substanciates theory No. 8 which states that saline elements are driven to deeper depths by longer rather than short leaching periods. At station 11 + 79 there was very little movement of salts below 10 feet during the first four leaching periods. During the fifth and longest leaching run of 136 days the salts were driven to a depth of 10 to 20 or more feet. The first four leaching runs had slight effect below 10 feet. P robably it takes in excess of 75 days continuous ponding to saturate the soil on Wilson's plots below 10 feet. At station 10 + 28, adjacent to the tile drainage lateral, there was considerable movement of water below the tile lines. A battery of piezometers was installed at depths of 5, 10 and 15 feet. Table 27 gives two sets of readings at station 10 + 28 and the arrows indicate the direction of ground water movement at each battery of piezometers.

Table 25. Percentages of soluble salts remaining in the soil after each leaching trial, Wilson Ranch, Imperial Valley, California

Depth of sampling	Station 10/53 42 feet from the tile line	Station 10/95 84 feet from the tile line	Station 11/79 midpoint between tile lines	Station 12/64 84 feet from the tile line	Station 13/06 42 feet from the tile line	Remarks
Feet	Percent	Percent	Percent	Percent	Percent	
0-1	59	94	113	74	97	After 1st leaching
	37	48	60	36	58	After 2nd leaching
	40	44	81	58	55	After 3rd leaching
	7	51	42	44	52	After 4th leaching
	36	34	17	50	42	After 5th leaching
1-2	141	142	110	68	101	After 1st leaching
	72	92	102	69	84	After 2nd leaching
	70	56	128	52	80	After 3rd leaching
	50	67	62	42	75	After 4th leaching
	66	24	32	48	31	After 5th leaching
2-3	103	122	110	95	100	After 1st leaching
	102	63	90	58	74	After 2nd leaching
	70	98	127	97	65	After 3rd leaching
	70	69	70	71	61	After 4th leaching
	80	65	26	79	42	After 5th leaching
3-4	138	104	89	120	110	After 1st leaching
	125	61	111	59	88	After 2nd leaching
	78	95	130	85	77	After 3rd leaching
	77	92	119	65	62	After 4th leaching
	106	63	66	71	56	After 5th leaching
4-5	130	143	93	190	89	After 1st leaching
	136	114	77	141	77	After 2nd leaching
	154	161	124	188	87	After 3rd leaching
	96	118	121	110	67	After 4th leaching
	122	114	91	133	70	After 5th leaching

Table 26. Conductance and tons of salt per acre foot, soil analysis for Tract No. 7, Wilson leaching study.

Depth of sample	Soil Analysis: $Kx10^5$ on a 5 to 1 soil solution; (T.A.F.) tons of salt per acre foot of soil											
	Pre-leaching		1st Run		2nd Run		3rd Run		4th Run		5th Run	
Feet	$Kx10^5$	T.A.F.	$Kx10^5$	T.A.F.	$Kx10^5$	T.A.F.	$Kx10^5$	T.A.F.	$Kx10^5$	T.A.F.	$Kx10^5$	T.A.F.
(Station 1 + 68)												
0-1	478	31.6							338	24.4	417	28.9
1-2	707	54.6							557	54.4	558	40.9
2-3	680	43.7							474	35.1	597	36.3
3-4	768	50.3							619	42.4	740	44.2
4-5	655	37.0							686	47.1	656	38.8
(Station 5 + 05)												
0-1	884	57.4							289	23.3	196	16.5
1-2	785	57.8							172	45.3	380	37.3
2-3	706	43.7							177	37.3	288	22.9
3-4	631	36.3							167	39.7	398	30.8
4-5	707	45.4							152	42.2	495	31.8
(Station 8 + 42)												
0-1	842	51.4							451	28.3	437	25.5
1-2	822	62.8							820	67.3	592	36.6
2-3	736	47.9							757	54.2	673	44.7
3-4	600	34.4							728	48.1	570	35.7
4-5	498	26.3							621	56.7	564	31.2
(Station 10 + 28)												
0-1	852	54.0			426	27.9			361	25.8	127	4.6
1-2	625	39.6			750	57.8			440	29.5	226	17.7
2-3	658	41.7			750	52.1			357	21.9	199	13.4
3-4	585	37.1			605	39.5			426	26.4	250	17.9
4-5	426	27.0			535	33.8			463	28.6	359	28.1
5-6	486	30.8							488	30.4	424	24.9
6-7	707	25.8							437	24.4	452	28.7
7-8	320	20.3							392	23.0	495	31.2
8-9	284	18.0							375	21.6	486	29.3
9-10	298	18.7							367	22.2	437	25.3
10-11	280	17.8							395	26.6	445	26.0
11-12	416	26.4							370	27.0	575	36.0
12-13	334	21.2							457	32.3	615	40.6
13-14	341	21.6							446	32.8	495	36.8
14-15	268	17.0							341	25.9	525	40.5
15-16	412	26.1							378	26.5	468	38.4
16-17	390	24.7							397	29.1	453	39.6
17-18	341	21.6							571	47.7	416	38.6
18-19	312	19.8							462	35.8	380	38.9
19-20	276	17.5							500	44.8	316	26.9

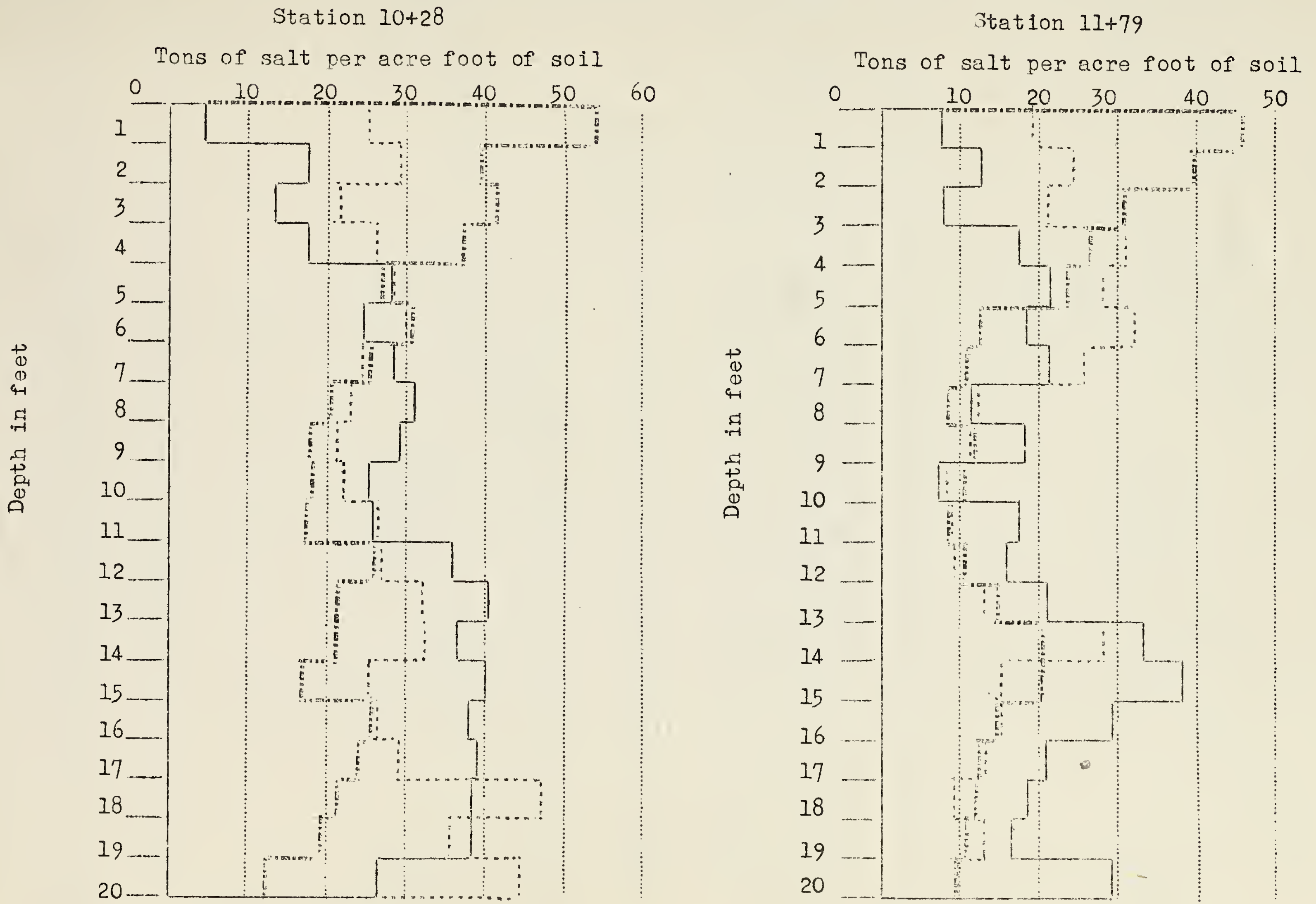
Table 26 (Continued)

Depth of sample: Feet	Pre-leaching: Kx10^5	T.A.F.	1st Run: Kx10^5	T.A.F.	2nd Run: Kx10^5	T.A.F.	3rd Run: Kx10^5	T.A.F.	4th Run: Kx10^5	T.A.F.	5th Run: Kx10^5	T.A.F.
(Station 10 + 53)												
0-1	842	45.5	445	26.9	260	16.9	274	18.3	147	3.2	270	16.3
1-2	631	38.1	660	53.7	390	27.4	399	26.6	378	19.9	336	25.0
2-3	631	36.5	510	37.6	520	37.0	382	25.5	265	25.4	453	29.1
3-4	610	34.1	637	47.2	647	42.5	400	26.7	245	26.4	535	36.1
4-5	490	26.6	594	34.6	550	36.3	613	40.8	245	25.4	535	32.5
(Station 10 + 95)												
0-1	655	41.7	636	39.3	318	20.0	278	18.5	292	21.4	222	14.2
1-2	505	31.8	636	45.0	468	29.1	265	17.7	321	21.3	137	7.7
2-3	610	37.6	595	46.1	390	23.7	552	36.8	398	25.8	332	24.3
3-4	465	29.8	445	30.8	293	18.0	426	28.4	400	27.4	354	18.9
4-5	327	14.0	307	20.0	298	15.9	337	22.5	189	16.5	276	16.0
(Station 11 + 79)												
0-1	721	45.7	713	51.8	436	27.4	558	37.2	270	19.2	215	7.6
1-2	625	39.6	614	43.4	585	40.2	763	50.9	377	24.5	248	12.9
2-3	481	30.5	510	33.7	436	27.3	579	38.6	353	21.4	184	7.9
3-4	417	26.4	396	23.6	481	29.2	514	34.3	484	31.3	320	17.5
4-5	368	23.3	349	21.7	312	18.0	432	28.8	413	28.1	386	21.2
5-6	193	12.2							360	32.2	350	18.3
6-7	169	10.7							334	25.8	328	21.4
7-8	134	8.5							206	12.4	195	11.1
8-9	181	11.5							168	11.3	282	18.1
9-10	165	10.5							158	8.7	328	7.3
10-11	136	8.6							139	8.9	282	17.6
11-12	162	10.3							157	9.5	250	16.0
12-13	234	14.8							158	13.0	295	21.1
13-14	318	20.2							340	28.8	404	53.2
14-15	323	20.5							193	15.6	430	38.4
15-16	229	14.5							186	15.1	392	29.4
16-17	192	12.2							178	13.3	324	20.8
17-18	189	12.0							150	9.6	279	18.8
18-19	171	10.8							182	13.3	258	16.8
19-20	156	9.9							136	9.2	354	29.2
(Station 12 + 64)												
0-1	645	43.0	495	31.8	264	15.7	372	24.8	291	18.8	365	21.3
1-2	584	38.1	380	25.9	329	19.4	298	19.9	287	15.9	328	18.3
2-3	437	29.5	425	27.9	293	17.0	428	28.6	371	21.0	392	23.4
3-4	533	33.0	595	39.7	323	19.4	418	27.9	368	21.4	410	23.6
4-5	353	20.0	595	37.9	446	28.2	564	37.6	393	22.0	477	26.6
(Station 13 + 06)												
0-1	770	51.3	637	49.9	493	29.8	424	28.3	412	26.5	309	21.3
1-2	672	44.8	614	45.3	520	37.4	535	35.7	512	33.4	223	14.0
2-3	657	43.8	685	43.8	550	32.3	427	28.5	421	26.7	285	18.6
3-4	635	42.3	713	46.5	568	37.3	490	32.7	421	26.4	380	23.7
4-5	695	46.2	615	41.0	535	35.7	600	40.0	479	31.1	535	32.4

Table 26 (Continued)

Depth of sample: Feet	Pre-leaching: Kx10^5	T.A.F.	1st Run: Kx10^5	T.A.F.	2nd Run: Kx10^5	T.A.F.	3rd Run: Kx10^5	T.A.F.	4th Run: Kx10^5	T.A.F.	5th Run: Kx10^5	T.A.F.
(Station 15 + 16)												
0-1	721	47.8							501	34.5	386	26.7
1-2	631	41.7							679	47.3	595	25.0
2-3	680	39.4							699	44.1	658	50.1
3-4	667	38.5							689	41.9	660	47.3
4-5	706	40.5							684	38.9	798	44.9
(Station 18 + 53)												
0-1	1340	89.2							857	59.8	656	50.1
1-2	635	42.4							910	61.0	733	52.3
2-3	579	38.6							800	52.6	779	47.0
3-4	613	40.8							653	43.9	605	35.1
4-5	625	41.7							495	29.5	392	22.3
(Station 21 + 90)												
0-1	634	47.3							217	15.4	423	25.8
1-2	706	54.0							291	18.2	673	55.3
2-3	634	40.7							456	32.7	639	39.6
3-4	427	22.4							468	28.2	596	37.3
4-5	328	16.1							300	15.1	495	28.2
(Station South East Corner)												
0-1	842	53.3							316	18.7	93	1.5
1-2	465	29.4							430	24.1	50	4.3
2-3	512	32.4							525	34.2	364	35.7
3-4	552	35.0							556	36.2	308	24.3
4-5	340	21.5							379	21.2	332	25.5
(Station North East Corner)												
0-1	631	39.3							1082	38.7	860	71.6
1-2	453	28.6							845	75.1	948	67.8
2-3	505	30.5							725	55.3	612	36.7
3-4	552	37.5							653	45.0	605	38.5
4-5	339	18.7							592	45.6	575	36.3
(Station on South West Corner)												
0-1	1470	99.0							823	56.6	364	22.1
1-2	805	59.3							1002	71.7	619	43.3
2-3	623	46.9							860	57.1	640	42.4
3-4	556	39.6							642	39.3	648	42.5
4-5	540	39.2							562	35.5	324	18.1
(Station North West Corner)												
0-1	1470	101.6							1290	86.7	955	76.6
1-2	1050	70.2							925	65.4	766	51.6
2-3	668	39.9							718	48.0	672	39.4
3-4	816	57.4							686	44.2	715	42.3
4-5	465	32.1							554	33.6	588	33.4

Figure 5. Wilson twenty foot soil sample total salt analysis.



Pre leaching soil analysis ....Analysis following 4th leaching period

__________ Analysis following the 5th leaching period

Table 27. Piezometer data at station 10 + 28 adjacent to tile drain on Tract No. 7, Wilson's leach plot, Imperial Valley, California.

Termination depth of piezometers below ground surface	During drying periods 4-15-49		During leaching periods 9-2-49	
	Static level of ground water in piezometer	Ground water movement	Static level of ground water in piezometer	Ground water movement
Feet	Feet	Direction	Feet	Direction
5	95.67	↓	97.30	↓
10	94.67		97.28	
15	97.33	↑	98.14	↑

The ground water is moving down to the tile from above and up the tile from below during both the drying and the leaching period. This is the normal ground water movement to a tile drainage lateral. Table 28 gives two sets of readings at Station 11 + 79, midway between two tile drainage laterals. The arrows indicate the direction of ground water movement.

Table 28. Piezometer data at station 11 + 79, midway between drainage laterals on Tract No. 7, Wilson's leach plot, Imperial Valley, California.

Termination depth of piezometers below ground surface	During drying periods 4-15-49		During leaching periods 9-2-49	
	Static level of ground water in piezometer	Ground water movement	Static level of ground water in piezometer	Ground water movement
Feet	Feet	Direction	Feet	Direction
5	98.00	↓	100.27	↓
10	97.98		98.74	
15	98.10	↑	98.41	↓

The piezometers indicate there was movement of ground water towards the 10 foot piezometer from both above and below during the drying period. The movement down from the five to the ten foot piezometer is very slight.

The head differential from the 15 foot piezometer to the ten foot one is 0.12 feet. This indicates there is some ground water movement upward from the 20 foot level during drying periods. This undoubtedly contributes to the high water table existing on the farm during the normal irrigation cycle. During leaching the piezometers indicate the direction of flow is downward to a depth of fifteen feet or more. There is a differential of 1.5 feet between the 5 and 10 foot piezometers. This suggests that there is some lateral movement of water to the tile drainage system from between the tile lines during leaching. The movement down below 10 feet was very slight and is indicated by the small amount of calculated deep seepage in table No. 22.

A complete chemical analysis was made of the soils at the two twenty foot sample locations, 10 + 28 and 11 + 79. These are shown in table 29 and table 30. The analysis was made by two foot increments. Analysis was made for total salts, calcium, magnesium, sodium, bicarbonate, sulfate, chloride, sodium cloride, calcium sulfate, percent sodium and percent calcium. A graphical representation of the pre and post leaching analysis for stations 10 + 28 and 11 + 79 is shown in figure 6. The total salts at the two locations were given in figure 5 by one foot increments. The analysis by one foot increments was made by the Soil Conservation Service and the complete analysis by two foot increments by the Imperial Irrigation District Laboratory. At station 10 + 28, next to the tile lateral, there was considerable decrease in calcium, sodium, and chloride during the leaching. The sodium chloride was reduced to less than one tenth the original salinity. The sodium and calcium percentage changed very little. At station 11 + 79, midway between two laterals the change was not as pronounced. The calcium, sulfates and chlorides were reduced, however, the sodium production was very slight. The sodium percentage for the surface foot increased from 24 percent prior to leaching to 60 percent following the 5th run. There was considerable reduction in the calcium percentage from 60 percent prior to leaching to 24 percent following the fifth run. The calcium sulfate content was high prior to leaching being 7381 parts per million at 10 + 28 and 11678 parts per million at 11 + 79. This indicates that there is slight if any benefit derived by applying gypsum to the heavy Imperial Valley soils to improve the infiltration rate.

Flow from drains

The flow volume from the tile drainage system was very low, due principally to the slowly permeable soil. The following tabulation gives the maximum tile discharge in gallons per minute during the leaching trials.

	Leaching trials				
Item	1st	2nd	3rd	4th	5th
Peak tile discharge G. P. M.	79	86	73	49	86

Table 29. Analysis of soil samples taken at station 10 + 28, adjacent to tile drainage lateral, Wilson ranch, Imperial Valley, California.

Depth of sample	Dissolved solids	Calcium Ca	Magnesium Mg	Sodium Na	Bicarbonate HCO_3	Sulfate SO_4	Chloride Cl
Feet	T.A.F.	M.e.l. P.p.m.	M.e.l. P.p.m.	M.e.l. P.p.m.	M.e.l. P.p.m.	M.e.l. P.p.m	M.e.l. P.p.m.
Prior to leaching, March 3, 1949							
0-2	56.88	200.92 - 4018	90.72 - 1107	194.86 - 4482	8.00 - 488	108.50 - 5208	370.00 - 13135
2-4	38.89	74.72 - 1494	61.62 - 752	197.67 - 4546	4.50 - 275	54.51 - 2616	275.00 - 9763
4-6	30.19	35.04 - 701	41.32 - 504	177.57 - 4084	4.00 - 244	54.93 - 2637	195.00 - 6923
6-8	28.41	34.68 - 694	30.54 - 373	161.16 - 3707	5.00 - 305	101.38 - 4866	120.00 - 4260
8-10	29.96	30.75 - 615	26.59 - 324	174.07 - 4004	4.75 - 290	141.66 - 6800	85.00 - 2947
10-12	29.90	58.63 - 1173	29.10 - 355	144.10 - 3314	5.50 - 336	138.83 - 6664	87.50 - 3106
12-14	28.43	36.11 - 722	24.25 - 296	157.70 - 3627	5.50 - 336	135.06 - 6483	77.50 - 2751
14-16	29.82	43.26 - 865	26.77 - 327	158.39 - 3643	6.00 - 366	144.92 - 6956	77.50 - 2751
16-18	36.03	74.00 - 1480	37.91 - 463	164.64 - 3787	5.50 - 336	186.05 - 8930	85.00 - 3018
18-20	30.44	82.58 - 1652	31.08 - 379	119.33 - 2745	5.50 - 336	162.49 - 7800	65.00 - 2308
Following 5th leaching period, October 30, 1950							
0-2	12.08	41.27 - 829	22.99 - 280	28.08 - 646	6.00 - 366	67.79 - 3254	18.75 - 666
2-4	16.34	36.82 - 736	25.87 - 316	60.41 - 1389	4.00 - 244	100.35 - 4817	18.75 - 666
4-6	27.09	55.41 - 1108	41.14 - 502	120.02 - 2760	3.75 - 229	111.32 - 5343	101.50 - 3603
6-8	27.57	47.53 - 951	37.73 - 460	150.21 - 3455	3.00 - 183	38.74 - 1860	193.75 - 6875
8-10	26.33	46.12 - 922	41.86 - 511	138.26 - 3180	2.75 - 168	35.99 - 1728	187.50 - 6656
10-12	29.60	61.49 - 1230	46.71 - 570	136.61 - 3142	3.25 - 198	86.56 - 4155	155.00 - 5503
12-14	38.67	92.95 - 1859	48.69 - 594	166.27 - 3824	2.25 - 137	165.66 - 7952	140.00 - 4970
14-16	38.13	158.37 - 3167	49.58 - 605	87.29 - 2008	5.25 - 320	213.74 -10260	76.25 - 2707
16-18	36.51	120.12 - 2402	49.04 - 598	107.39 - 2470	4.50 - 275	228.30 -10958	43.75 - 1553
18-20	36.87	89.38 - 1788	31.44 - 384	152.44 - 3506	3.75 - 229	236.96 -11374	32.50 - 1154

Table 30. Analysis of soil samples taken from station 11 + 79, midway between tile drainage laterals, Wilson ranch, Imperial Valley, California.

Depth of sample	Dissolved solids	Calcium Ca	Magnesium Mg	Sodium Na	Bicarbonate HCO_3	Sulfate SO_4	Chloride Cl
Feet	T.A.F.	M.e.l. P.p.m.	M.e.l. P.p.m.	M.e.l. P.p.m.	M.e.l. P.p.m.	M.e.l. P.p.m.	M.e.l. P.p.m.
Prior to leaching, February 28, 1949							
0-2	49.37	241.67 - 4833	66.11 - 807	95.38 - 2194	16.00 - 976	171.66 - 8240	215.00 - 7633
2-4	29.95	63.99 - 1280	34.31 - 419	147.57 - 3394	6.00 - 366	79.87 - 3834	160.00 - 5680
4-6	23.48	38.61 - 772	29.82 - 364	114.60- 2636	6.75 - 412	103.78 - 4981	72.50 - 2574
6-8	17.15	21.45 - 429	22.46 - 274	84.88 - 1952	6.25 - 381	95.04 - 4562	27.50 - 976
8-10	14.21	15.73 - 315	18.32 - 224	73.05 - 1680	6.75 - 412	72.85 - 3497	27.50 - 976
10-12	12.62	15.73 - 315	16.17 - 197	62.76 - 1443	9.50 - 580	60.16 - 2888	25.00 - 888
12-14	23.53	49.34 - 987	29.82 - 364	96.31 - 2215	6.75 - 412	143.72 - 6899	25.00 - 888
14-16	31.69	88.66 - 1773	40.78 - 498	106.88 - 2458	6.50 - 397	204.82 - 9831	25.00 - 888
16-18	23.99	53.98 - 1080	31.80 - 388	94.01 - 2162	6.00 - 366	146.29 - 7022	27.50 - 976
18-20	17.35	29.67 - 593	21.02 - 256	79.19 - 1821	6.50 - 397	98.38 - 4722	25.00 - 888
Following 5th leaching period, October 30, 1950							
0-2	15.59	29.67 - 593	19.76 - 241	72.94 - 1678	11.00 - 671	52.62 - 2526	58.75 - 2086
2-4	16.77	23.95 - 479	19.40 - 237	91.42 - 2103	5.25 - 320	52.02 - 2497	77.50 - 2751
4-6	26.27	33.96 - 679	32.52 - 397	149.07 - 3429	5.00 - 305	68.05 - 3266	142.50 - 5059
6-8	20.30	28.60 - 572	26.59 - 324	106.37 - 2447	4.00 - 244	77.56 - 2723	80.00 - 2840
8-10	30.31	27.17 - 543	22.10 - 270	105.48 - 2426	4.00 - 244	105.75 - 5076	45.00 - 1598
10-12	18.28	24.31 - 486	21.20 - 259	92.60 - 2130	5.50 - 336	97.61 - 4685	35.00 - 1243
12-14	28.03	67.21 - 1344	36.47 - 445	108.51 - 2496	6.00 - 366	163.69 - 7857	42.50 - 1509
14-16	35.41	111.90 - 2238	47.97 - 585	109.58 - 2520	4.00 - 244	215.45 -10342	50.00 - 1775
16-18	21.42	37.54 - 751	26.23 - 320	102.47 - 2357	4.00 - 244	102.24 - 4908	60.00 - 2130
18-20	23.63	62.21 - 1244	31.08 - 379	88.72 - 2041	5.50 - 336	124.01 - 5952	52.50 - 1864

Figure 6. Twenty foot soil sample analysis - Dotted line is analysis prior to leaching and solid line is analysis following the fifth leaching period *Analysis is plotted in parts per million X 10^{-3}

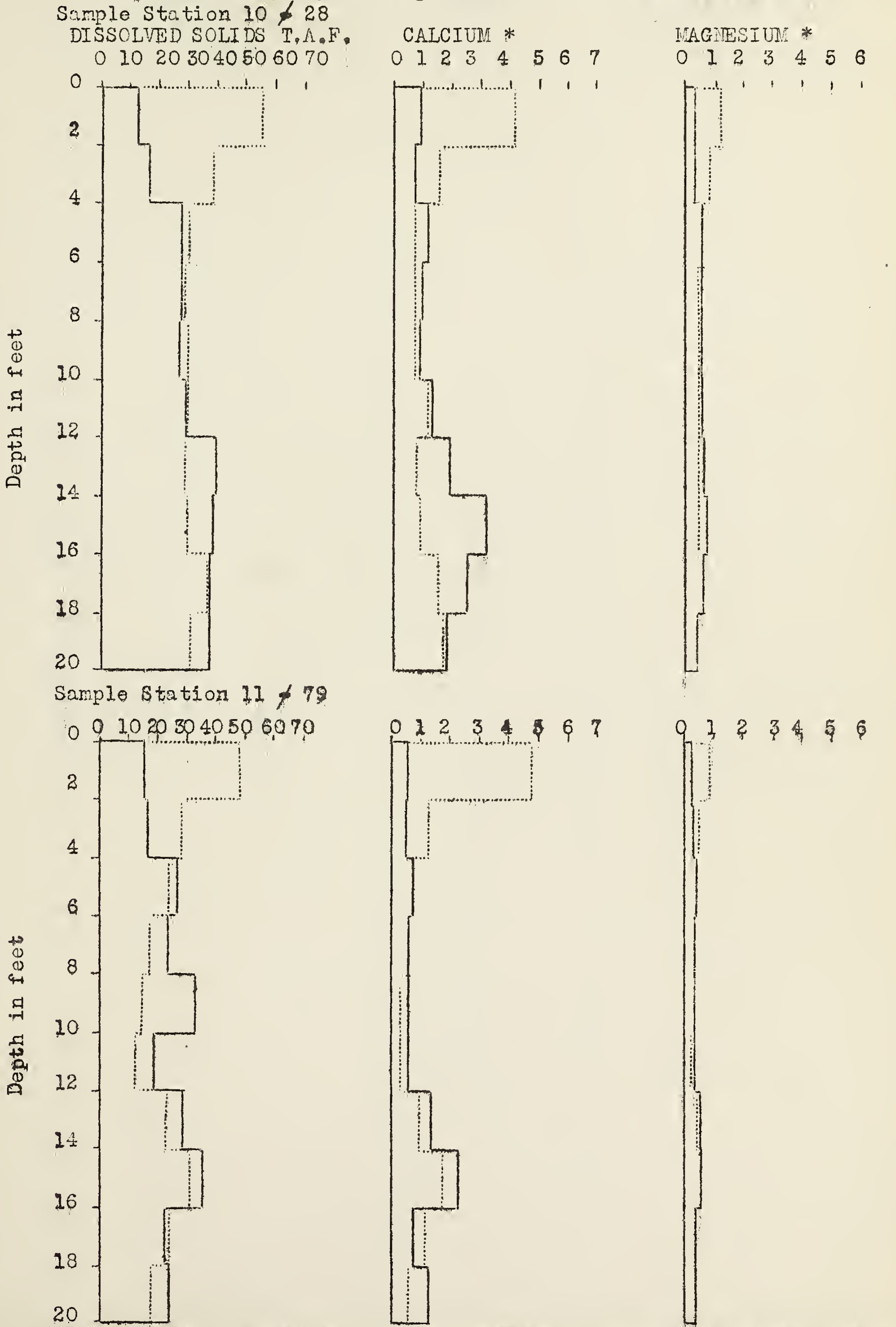
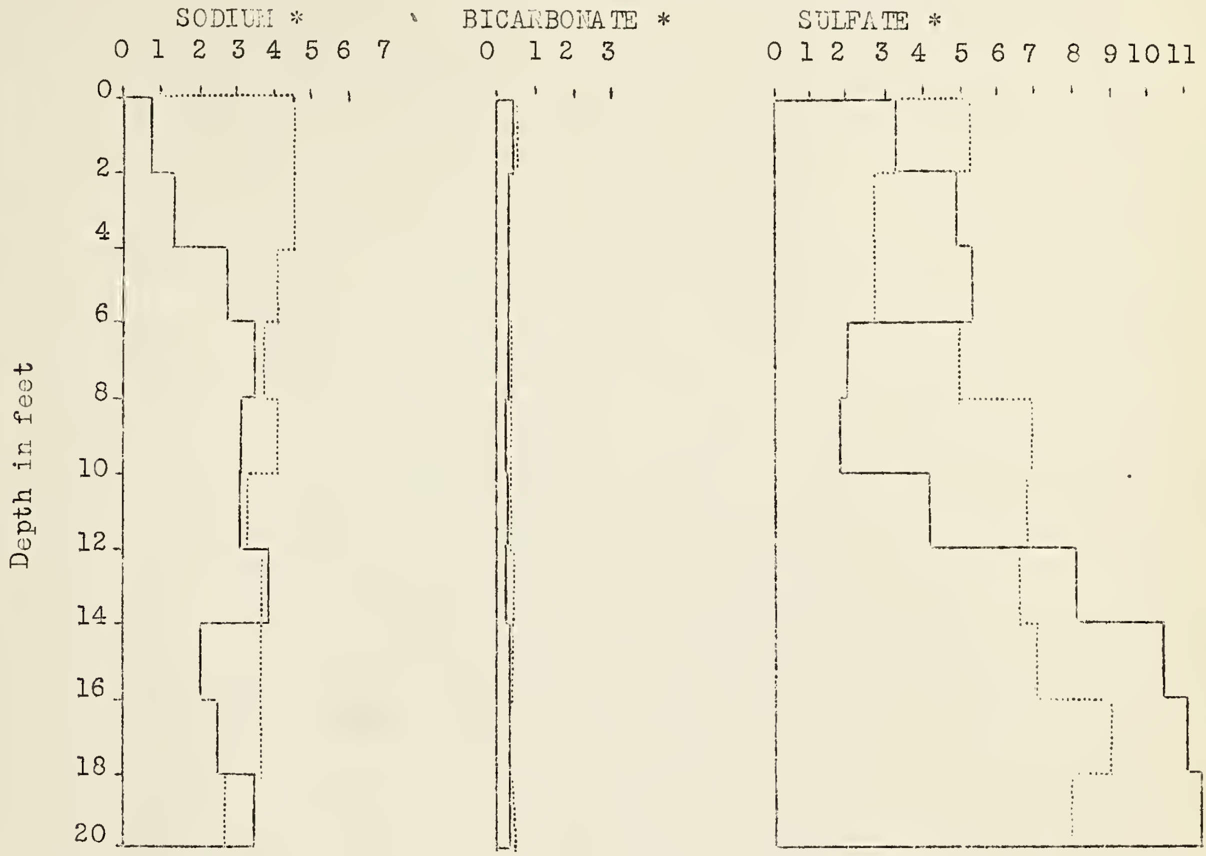


Figure 6. Twenty foot soil sample analysis - Dotted line is analysis prior to leaching and solid line is analysis following the fifth leaching period * Analysis is plotted in parts per million X 10^{-3}



Sample Station 11 ∤ 79

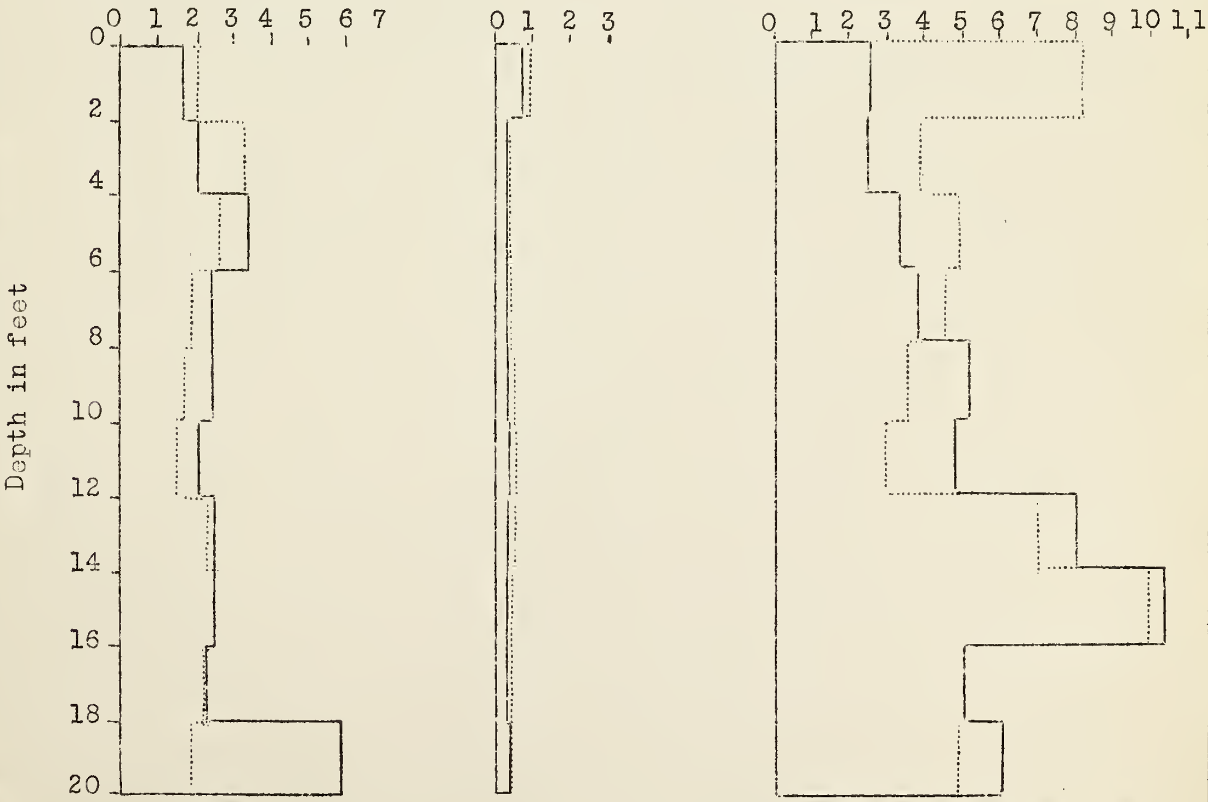


Figure 6. Twenty foot soil sample analysis - Dotted line is analysis prior to leaching and solid line is analysis following the fifth leaching period * Analysis is plotted in parts per million X 10^{-3}

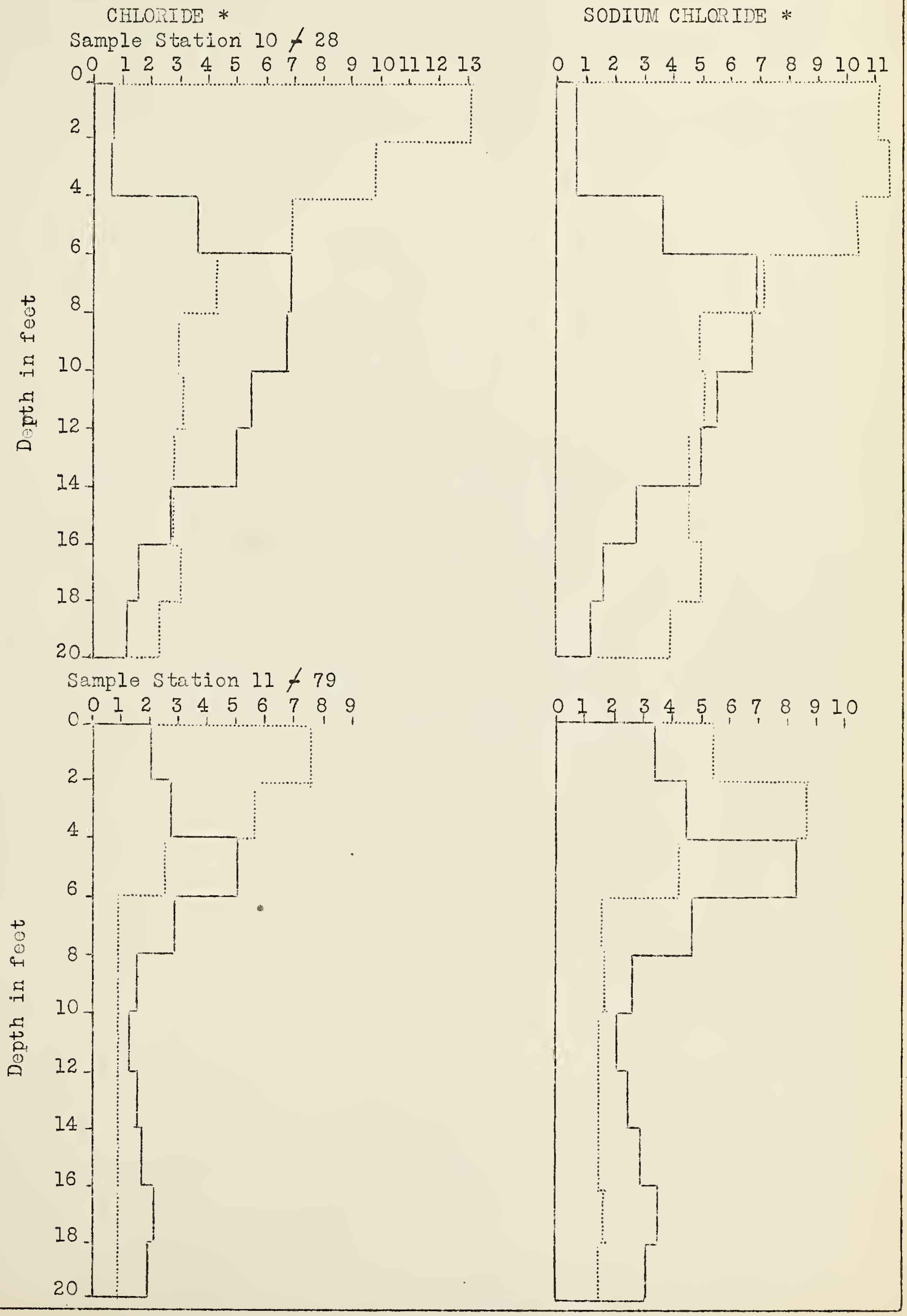
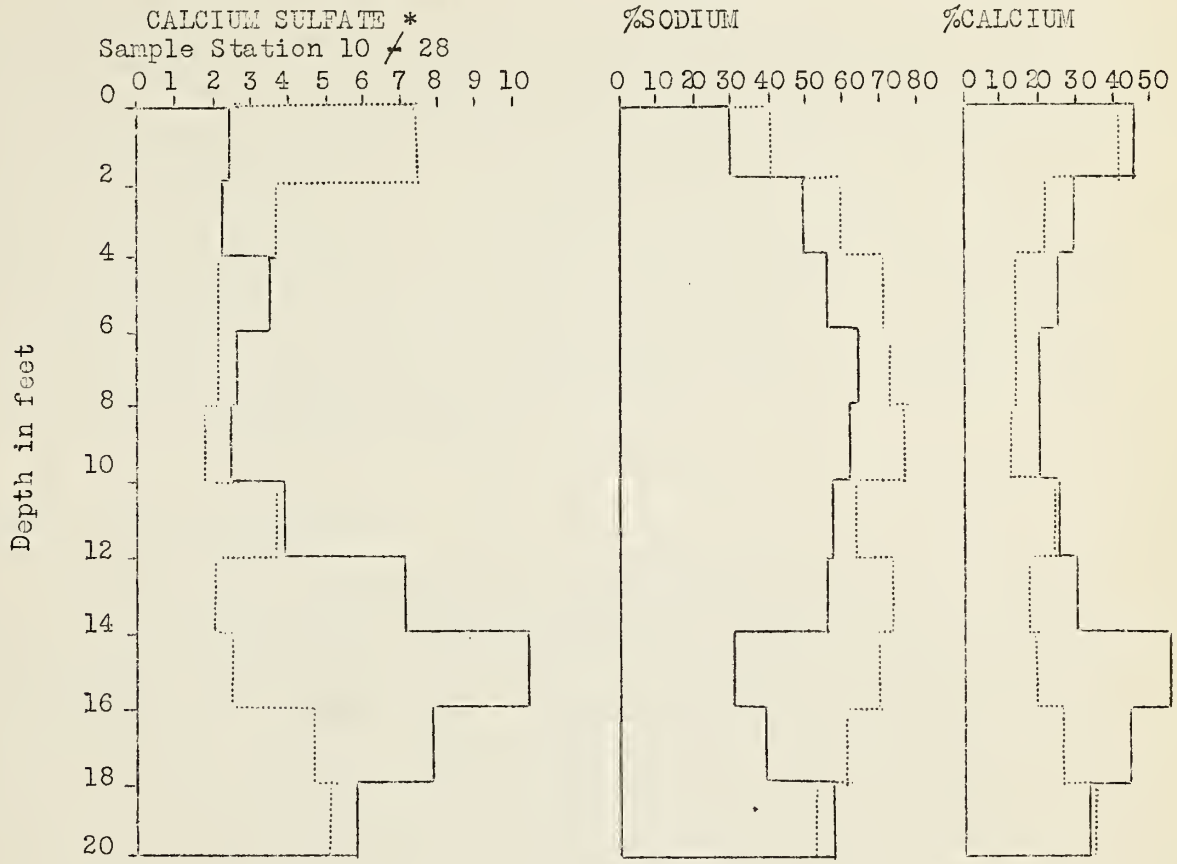
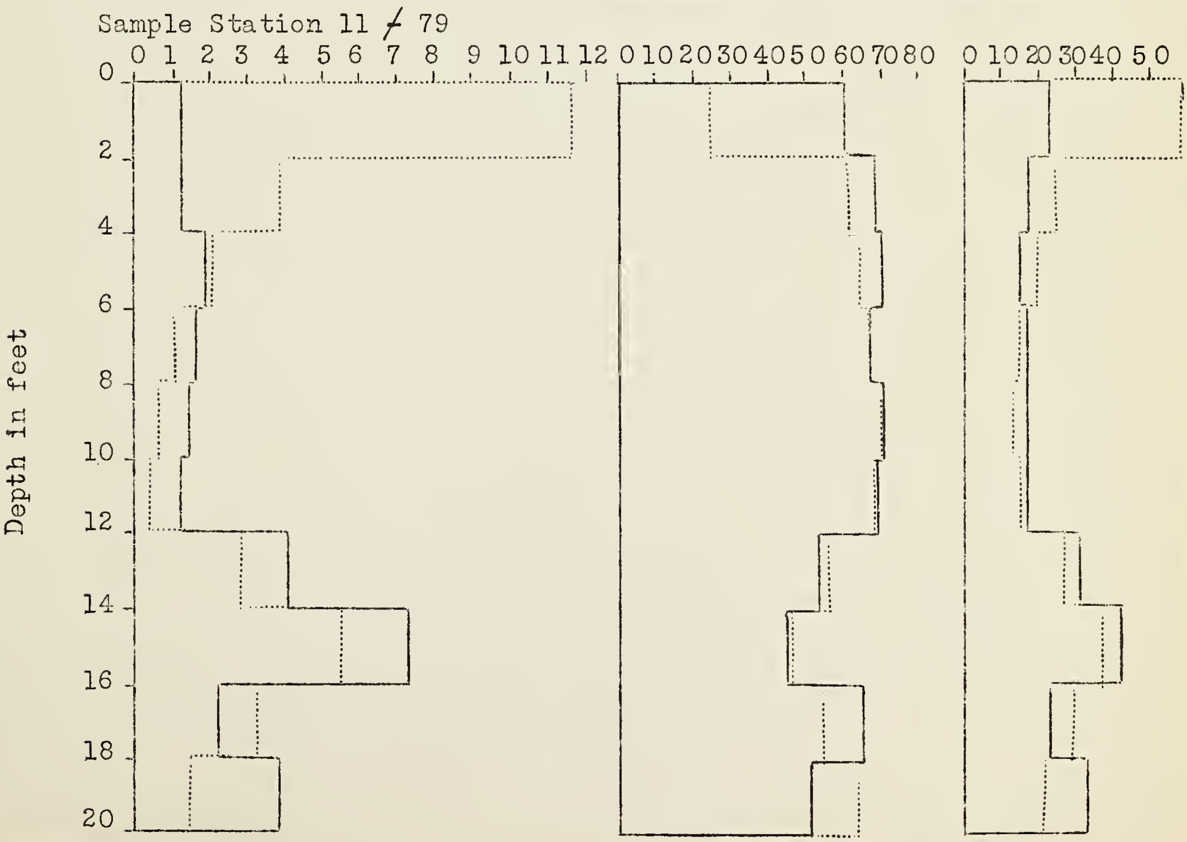


Figure 6. Twenty foot soil sample analysis - Dotted line is analysis prior to leaching and solid line is analysis following the fifth leaching period * Analysis is plotted in parts per million X 10^{-3}



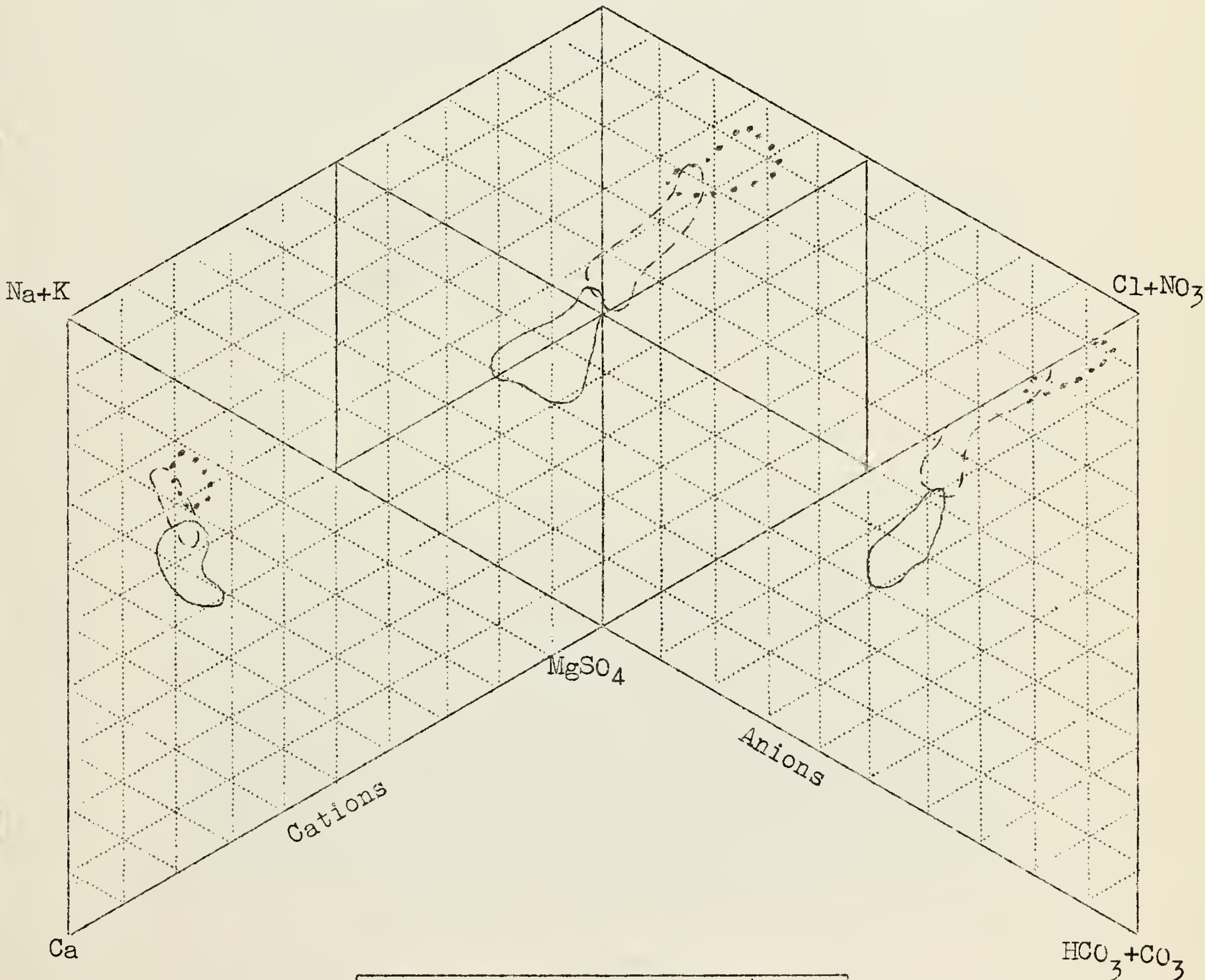


The reduction in quantity of flow during third and fourth run substanciate theory No. 4 which states that the soil surface deflocculates over a period of time in the leaching plots. Between the fourth and fifth leaching runs the surface was plowed several times. This fractured the deflocculated surface and nearly doubled the rate of flow from the drainage system. At the close of the fifth leaching run the deflocculated layer had reformed in the leaching plots. A comparison of the chemical character of, the water applied, the water surface wasted and the tile drainage effluent is given in the geochemical classification chart figure 7. The chart is drawn with respect to the percentages of the various locations and anions present in the water during the 5 leaching runs. The chart indicates that considerable sodium chlorides was picked up and removed by both the surface waste and the tile drainage effluent.

Segregation of surface soils

A study was made of the surface soil characteristics in the leaching plots. A heavy deflocculated-segregated surface soil condition was formed during the leaching process. This deflocculated-segregated soil layer was more pronounced in the heavier soils and had considerable effect upon the infiltration rate. Figure 8 gives a location sketch of the sample sites and a photograph of the soil at the midpoint between dikes and at a point adjacent to a dike. There are three distinct soil layers showing in the top five inches of the soil. The wave action of the water in the ponds stirs up the top layer of soil and the wave action is very evident at the edges of the ponds. The surface crust at the edges of the ponds averaged about one inch in thickness. The semi-crust layer was $1\frac{1}{2}$ to 2 inches thick but was not as pronounced as the crust at either sample location. This study substanciates theory No. 4 which states that the surface soil is deflocculated which greatly influences the infiltration rate. Table 31 shows the Bouyouces analysis, permeability and the apparent specific gravity of the deflocculated segregated soil surface in the leaching ponds. A comparison of the Bouyouces analysis for sample "A" & "B" indicate that there was some movement of the clays in the ponds. The soils adjacent to the dikes were considerable higher in percent silt plus clay than those in the center of the ponds. This would indicate that some silt and clay was moved to the edges of the pond by the wave actien of the leaching water. The percentage of clay is also higher in the crust than it is in the semi-crust. This would also tend to prove that there is some segregation by the water action. The percentage of colloidal clay is greater near the center of the ponds and less at the edges at both sample "A" and "B" locations. The percentage of colloidal clay at sample "A" was only 28 percent in the crust and 43.5 in the semi-crust. At sample "B" location the colloidal clay content was 39 percent in the crust and 45 percent in the semi-crust. This reduction of colloidal clay in the surface crust indicates that there was considerable colloidal clay picked up by the leaching water and carried off the field in the leaching water. This was also borne out in analysis of the silt content of the water applied and of the surface waste water.

Figure 7. Geochemical chart depicting the leaching, surface waste and drainage waters.



Leach water	
Surface waste	
Tile drainage effluent	

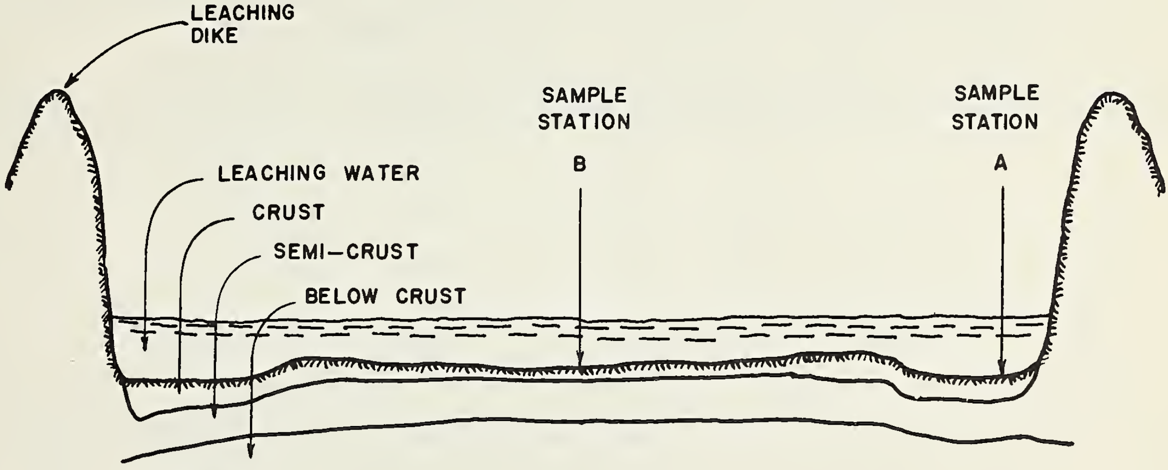


FIGURE 8A
LEACHING PLOT PROFILE SHOWING THE DEFLOCCULATED SEGREGATED CRUST, THE SEMI-DEFLOCCULATED CRUST AND THE SOIL BELOW THE DEFLOCC-ULATED SURFACE. SAMPLES FOR PERMEABILITY RUNS AND ANALYSIS WERE TAKEN AT SAMPLE STATIONS "A" AND "B" STATION "A" WAS TAKEN NEXT TO THE LEACHING DIKE AND "B" WAS TAKEN AT A POINT MIDWAY BETWEEN TWO DIKES.

B A

FIGURE 8B
SOIL SAMPLES TAKEN AT SAMPLE STATIONS "A" AND "B", SAMPLE "A" WAS TAKEN NEXT TO A DIKE AND "B" MIDWAY BETWEEN TWO DIKES.

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Table 31. Bouyoucos analysis of the deflocculated surface soils following the fourth leaching run on the Wilson leaching plots, Imperial Valley, California.

Item	Sample "A" 1/			Sample "B" 2/		
	Crust	Semi-crust	Below-crust	Crust	Semi-crust	Below-crust
Percent silt plus clay	95	90	88	88	81	81
Percent silt	40	40	38	42	30	32
Percent clay	55	50	50	46	51	49
Percent colloidal clay	28	43	44	39	45	41

1/ Sample"A" taken next to the leaching dike.
2/ Sample "B" taken in center between dikes.

Table 32. Permeability at the deflocculated surface soils at sample "B" location following the fourth leaching run on the Wilson leaching plots, Imperial Valley, California.

Location	Depth sample			
	Inches	C.C. per sq. cm. per hr.	Gal. per sq. ft. day	In./hr.
3/4" surface crust	0 - 5	0.03	0.14	0.01
2" semi-crust	3/4 - 5 3/4	0.06	0.28	0.02
Below crust	2 - 7	0.16	0.82	0.06

Figure 9a shows a plot which was not reclaimed. The major portion of this land has no native growth whatsoever due to the extreme saline condition of the soil surface. Figure 9b shows an adjacent plot which has been reclaimed by leaching and tile drains. This plot supports a good stand of barley, for the first crop following leaching.

FIGURE 9A--CONDITION OF THE SURFACE SOIL AT WILSONS RANCH PRIOR TO RECLAMATION BY TILE DRAINAGE AND LEACHING. THE SURFACE IS VERY SALINE AND HAS REACHED THE STAGE OF BEING DELIQUESCENT.

FIGURE 9B--CONDITION OF THE BARLEY CROP AT WILSONS RANCH JUST PRIOR TO HARVEST. NOTE THE CAT-TAILS (TYPHA LATIFOLIA) WHICH ARE A CARRY OVER FROM THE LEACHING PROGRAM.

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Table 33. Analysis of the deflocculated surface soil on Tract No. 7, Wilson leaching plots. 1/

Sampled April 4, 1950
Analysis in Parts per Million

	Sample Location A			Sample Location B		
Chemical	3/4" Crust	$1\frac{1}{4}$" Semi-crust	Below crust	3/4" Crust	$1\frac{1}{4}$" Semi-crust	Below crust
$K \times 10^5$ @ 25°C (5-1) Solution	133	74	63	376	133	229
TDS TAF	10.67	6.41	5.56	26.08	12.08	16.01
B_2O_3	None	None	None	None	None	None
Ca	340	229	169	1120	404	365
Mg	192	80	43	553	133	187
Na	1051	635	650	2488	1450	1873
CO_3	None	None	None	None	None	None
HCO_3	1708	1220	824	1068	763	610
SO_4	979	510	562	3817	1397	2641
Cl	1065	533	533	3994	1864	2130
NO_3	None	None	None	None	None	None
% Na	66.4	67.3	75.4	59.8	73.0	77.2

1/ Analysis of the deflocculated surface condition on Wilson's ranch (T 14S R 15E Tracts 84 & 64) following the fourth leaching run. Sample "A" was taken next to a dike and "B" was taken in the center between two dikes.

LABORATORY LEACHING STUDIES

The laboratory leaching studies were not carried out as extensively as the field studies. However, sufficient data were recorded on the various laboratory phases to determine the value of each method. The laboratory work consisted of the following:

1. Gypsum impregnated water was used in an effort to replace exchangeable sodium and increase the infiltration rate and permeability of heavy saline soils.

2. Detergent impregnated water was used as a wetting agent in an effort to increase the infiltration rate and permeability of heavy saline soils.

3. A series of 6 foot long, 10 inch diameter, galvanized, iron, tanks were used to determine permeability of stratified soils and to test theories on reducing the leaching time required to reclaim a given soil.

Gypsum Studies

A number of slowly permeable, in place, soil samples were brought into the laboratory and permeability studies, using the falling head permeameter, were made with both irrigation water and irrigation water containing 0.1 percent of gypsum ($CaSO_4$). Gypsum impregnated water was used in an effort to replace exchangeable sodium and to increase the permeability of heavy soils.

Two types of soils were used in the test. One having a permeability of 0.08 and the other 4.4 cubic centimeters per square centimeter per hour. Four replicates were run of each soil to determine the effect of the gypsum. After the permeability rate had become stabilized, gypsum impregnated water was applied in the permeameter. There was no increase in the permeability of either the moderate or slowly permeable soil samples. The permeability results indicate that the application of gypsum to Imperial Valley soils has no appreciable effect upon the rate of infiltration of the permeability.

Detergent Studies

A number of slowly permeable, in place, soil samples were brought into the laboratory and permeability studies were made using the falling head permeameter. The tests were made with regular irrigation water and with water containing 0.1 percent of sulphonated ester of ethel alcohol. The soil used in the study was a heavy clay soil which was highly saline. The chemical analysis for the soil samples is given in table 34.

Table 34. Chemical analysis of soil used in the laboratory detergent studies, Imperial Valley, California.

Item	Soil Analysis 1/		
	M.e.l. 2/	P.p.m. 3/	T.a.f. 4/
Dissolved salts		154,430	308.9
Calcium	1788	35,750	71.5
Magnesium	240	2,934	5.9
Sodium	1065	24,493	49.0
Bicarbonate	4	275	0.6
Sulfate	212	10,152	20.3
Chloride	2025	71,888	143.8

1/ Silica, iron and aluminum not determined.
2/ M.e.l. - Milligram equivalents per litre.
3/ P.p.m. - Parts per million.
4/ T.a.f. - Tons per acre foot.

The samples tested with irrigation water had permeability rates so low that they could not be measured in the falling head permeameter. The samples tested with detergenated water had a permeability which ranged from 0.004 to 0.014 cubic centimeters per square centimeter per day during a 28 day run. Analysis of the soil columns after the permeability tests were terminated, revealed that there were no apparent leaks or channels in the samples.

In conjunction with the permeability studies, a study was made of the toxic effect of detergents on crop growth. Fourteen pots of plants were started. Seven pots were planted to Double Dwarf Milo and seven to Black-eyed Cow Peas. The seeds were planted in a clay loam soil which was relatively saline free and which had shown a good crop growth for two previous years. The various pots were irrigated with water that was detergent free and with water containing various concentrations of detergent up to 1 percent. The detergent treated ones slowly degenerated and eventually died.

The conclusions reached were that detergents appear to be quite toxic to plants. This is rather important as a large amount of detergent could be absorbed by the soil during leaching and might prove as harmful as the saline elements present. The increase in permeability was apparent but would be offset by the high cost of the detergents and the toxic effects.

Laboratory Tank Studies

A series of 6 foot long, galvanized iron, tanks 10 inches in diameter were used in the laboratory leaching study. The tanks were provided with drain openings in the bottom and manometer tubes along the sides at one foot intervals. The manometer tubes were used to determine the permeability

of the 5.5 foot column of soil. A one inch thick steel grill was placed in the bottom of the tanks to act as a drain. This grill was covered with a 1/4-inch meshed hardware wire screen and a fine meshed copper screen to prevent the soil in the bottom of the tanks from passing out the bottom drain. A one inch layer of sand was placed on the screens to act as a filter. Various soils were then carefully packed into the tanks and water was introduced at the tops. A chemical analysis was made of the soils prior to and following leaching. Chemical analysis was also made of the leaching and drainage effluent water. These analysis consisted of measuring total dissolved salts and total chlorides by the pipette method. The soils were analyzed for permeability and texture before being placed in the tanks.

Results from two tank runs are given in table 35. The tests were made using regular irrigation water on medium permeable soils.

Table 35. Results of two laboratory leaching studies, Imperial Valley, California.

Item	Units	Sample No. 26 Immel Ranch	Sample No. 27 Wright Ranch
Soil permeability	Cc/Sq/cm/hr.	0.55	1.50
Leaching time	Days	11	4
Depth of water applied	Feet	28.5	31.1
Chlorides in soil			
Before leaching	Tons/ac/ft.	1.30	0.65
After leaching	Tons/ac/ft.	0.04	0.002
Total dissolved salts			
Before leaching	Tons/ac/ft.	21.64	11.46
After leaching	Tons/ac/ft.	1.62	1.56

A comparison of the leachate from the laboratory and field trials are given in table 36.

The following factors have been revealed in making the leaching runs in the laboratory tanks.

1. Leaching is accomplished in a very short period of time. Large amounts of water can be drained through the tanks because the drain is effective over the entire bottom of the soil column.

2. Almost complete leaching of saline elements can be accomplished in from 4 to 10 days in the tanks. Similar field leaching studies require 30 to 300 days for a partial leaching of saline elements.

3. The salinity trend of the tile drainage effluent closely approximates the drainage effluent from the laboratory tanks.

4. The tank studies indicate one foot of water percolating the soil will reclaim light soils and 2 feet of percolation will be required on heavy soils.

Table 36. Comparison of leachate from laboratory and field leaching studies, Imperial Valley, California.

Depth of water removed by the drainage system	Tons per acre of saline elements in the drainage effluent												
	Laboratory studies				Field leaching studies								
	Immel		Wright		O'Dwyer		Ross		Simons		Immel		Wilson
Acre feet/acre	T.D.S.	Cl.	T.D.S.	Cl.	T.D.S.	Cl.	T.D.S.	Cl.	T.D.S.	Cl.	T.D.S.	Cl.	T.D.S.
0.0	97	50	48	21	13	4	19	8	46	30	62	25	68
.1	95	43	46	19	10	3	16	6	64	26	59	28	68
.2	94	39	45	18	10	3	16	5	55	25	61	29	68
.3	92	34	43	17	9	2	12	5	53	29	62	30	60
.4	90	31	41	16	8	2	16	6			67	30	53
.5	88	27	38	16	8	2	19	7			65	29	49
.6	86	24	35	15	8	2					65	29	49
.7	84	21	30	15							65	29	49
.8	81	18	28	13									49
.9	78	16	27	12									
1.0	75	14	26	11									
1.1	70	12	23	11									
1.2	65	10	20	10									
1.3	60	9	17	9									
1.4	52	7	15	8									
1.5	40	6	13	8									
1.6	22	4	12	7									
1.7	18	3	11	6									
1.8	16	2	10	5									
1.9	14	2	9	4									
2.0	12	1	8	4									

COMPARISON OF ALL LEACHING STUDIES

One of the most revealing comparisons to be made in reviewing the data on the various leaching studies made in Imperial Valley deals with the relationship between the amount of water leached through the soil and the rate of removal of saline elements. In all the studies, the quantity of water removed by the drains was measured and reduced to the equivalent depth of water over the entire area. At the same time samples of this water were periodically analyzed for total salts and for chloride content. Table 36 is a comparison of the leachates from the various studies during the leaching cycle. The contrast between the laboratory studies where a total of 2 feet depth of water passed through the soil and the field studies where less than one foot depth passed through indicates the desirability of running tank studies.

Figure 10 is a series of curves drawn by plotting the ratio of depth of water percolating the soil in feet, to the saline elements removed tons per acre, in the leaching studies. These curves fall in an interesting pattern and suggest that the end point of leaching light soils would be when approximately one-half a foot to one foot of water passes through the soil profile to the drain. The end point of leaching the finer textured soils might be reached when approximately one foot to two feet of water passed through the soil profile to the drain.

ADDITIONAL FLOW DATA

Since the entire efficiency of the leaching program revolves around the factor of the flow of water through the profile, it seems logical to discuss briefly some of the flow studies which were made on the tile systems in Imperial Valley. A large number of tile drainage systems were observed in order to determine their efficiency during both normal irrigations and under an extensive leaching program. Discharge data were obtained from most of the drains with the Bradshaw type recorder and by spot checks of flows from tile systems. Table 37 is a summary of data on flow from a number of the drainage systems that were checked. These data indicate that during ordinary irrigation from 2 to 16 percent of the amount of water applied is removed by the tile drainage system. During leaching 20 percent or more may be removed by the tile drainage system.

A comparison has been made between the prorated permeabilities of the various plots tiled and the percentage of outlet drainage flow of the tile system. It has been found that a correlation exists between permeability and percent of flow. The more permeable soils trend towards a larger percentage of flow. Table 38 shows the relationship between permeability and percentage of applied water which finds exit in the tile system during normal irrigations.

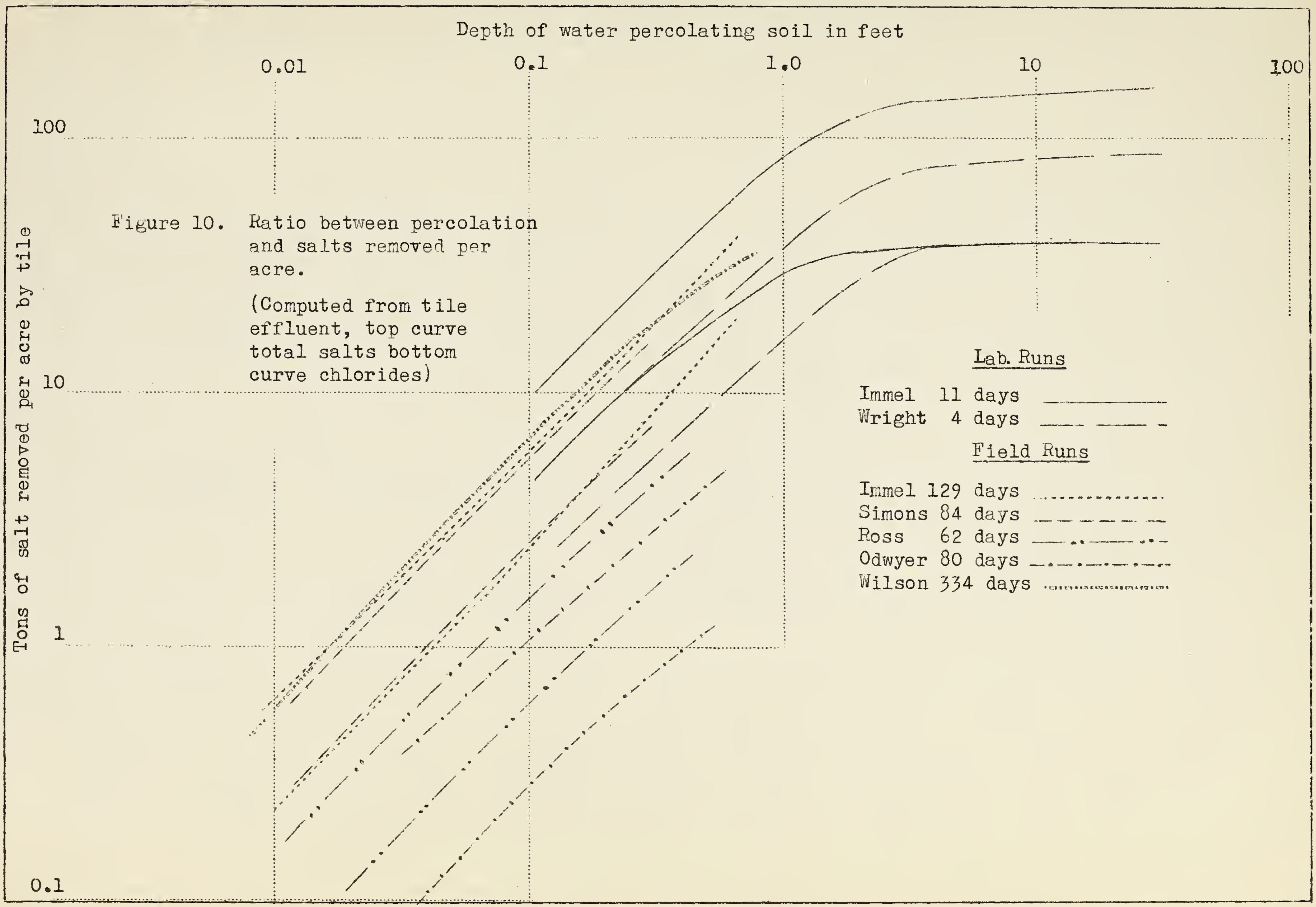

Figure 10. Ratio between percolation and salts removed per acre.

(Computed from tile effluent, top curve total salts bottom curve chlorides)

Table 37. Summary of data on flow from tile lines, Imperial Valley, California.

Location of plot	Period	Input water applied to plot	Outlet drainage from tile system		Remarks
		Ac. ft.	Ac. ft.	Percent	
Meloland Home Plot	1943	65.97	4.54	6.9	Irrigation
Meloland Home Plot	1944	87.56	16.69	19.0	Leaching
Meloland Home Plot	1947	76.38	6.21	8.1	Irrigation
Meloland Home Plot	1948 January-June	23.48	2.41	9.4	Irrigation
Jim Bridger	1942	161.5	14.9	9.2	Irrigation
Homola	1 irrigating cycle	6.1	0.49	8.0	Irrigation
O'Dwyer-Mets	80-day leaching	77.0	25.4	33.1	Leaching
Wahl	150 days	143.2	12.7	8.9	Irrigation
Wilson	30 days leaching	125.4 1/	14.1	11.1	Leaching
Wilson	44 days leaching	170.2 1/	13.8	8.1	Leaching
Wilson	74 days leaching	273.7 1/	24.6	9.0	Leaching
Wilson	48 days leaching	81 1/	14.9	18.4	Leaching
Wilson	136 days leaching	630 1/	45.2	7.2	Leaching
Wilson					Irrigation
Koluvek 13-16 Sec.6	15-day cycle	4.0	1.37	34.2	Irrigation
Zajicek 13-16 Sec.6	23-day cycle	30.1	.83	2.8	Irrigation
Suchy	12-day cycle	19.8	2.65	13.4	Irrigation
Mets 14-15 Sec. 8	16-day cycle	68.5	6.8	9.9	Irrigation
Wright 12-13 Sec.26					
Plot 1	11-day cycle	12.5	.62	5.0	Irrigation
Plot 2	11-day cycle	20.0	1.27	6.4	Irrigation
Plot 3	24-day cycle	20.9	1.25	6.0	Irrigation
Plot 4	24-day cycle	20.9	1.25	6.0	Irrigation
Plot 5	13-day cycle	19.7	0.62	3.2	Irrigation
Sperry 12-13 Sec.27					
Plot 1	19-day cycle				Irrigation
Plot 2	19-day cycle				Irrigation
Plot 3	16-day cycle	14.7	1.11	7.6	Irrigation
Plot 4	16-day cycle	16.0	.80	5.0	Irrigation
Plot 5	19-day cycle	60.3	9.49	15.7	Irrigation
Suchy 13-16 Sec.5-6	18-day cycle	99.6	12.40	12.4	Irrigation
Chalupnick 14-15 Tr. 64 and 68	18-day cycle	56.2	5.71	10.2	Irrigation

1/ Surface waste subtracted.

Table 38. Correlation between permeability of the soil and the percentage of water removed by the drainage systems during normal irrigations, Imperial Valley, California.

Soil	Permeability		Water removed by drainage system
Gal/sq.ft./day	Cc/sq.cm./hr.	Inches per hr.	Percent
4	0.7	0.2	2
7	1.4	0.5	3
11	2.2	0.7	4
15	2.9	1.0	5
18	3.7	1.2	6
22	4.4	1.5	7
26	5.2	1.7	8
30	5.9	2.0	9
33	6.6	2.2	10
37	7.4	2.5	11
41	8.1	2.7	12
44	8.9	3.0	13
48	9.6	3.2	14
52	10.4	3.5	15
56	11.1	3.7	16

Ponding time estimates

The time required for ponding leaching water on the surface to satisfactorily reclaim the soil is dependent upon the overall permeability of the soil and the location of permeable stratums within the profile. A soil profile that has a coarse textured stratum from 5 to 9 feet is easier to drain and reclaim than one having a fine textured stratum from 5 to 9 feet.

A summary of data, from the leaching studies, on the duration of ponding time necessary to reclaim saline soils is given in table 39. These are to be used in conjunction with a tile drainage system that is adequately designed with respect to the soil permeability.

Table 39. Duration of leaching with respect to soil permeability and location of permeable strata, Imperial Valley, California.

Permeability		Duration leaching
1 to 5 feet, depth	5 to 9 feet, depth	Days
Rapid	Rapid	0
Moderate	Rapid	30
Rapid	Moderate	60
Slow	Rapid	90
Rapid	Slow	120
Moderate	Moderate	150
Slow	Moderate	180
Moderate	Slow	210

Soils with a rapid permeability to a depth of nine feet can usually be reclaimed during the growing of a crop of sesbania following the installation of a tile drainage system. If the surface is highly saline the land might require leaching for 15 days prior to planting the sesbania.

COSTS AND BENEFITS OF LEACHING

The costs and benefits of the leaching program are hard to access. It is hard to place a relative increase in value to land which in one state is non-productive, due to waterlogging and saline impregnations, and in the other state is highly productive and reclaimed. The alternative presented herewith is to detail the costs and to cite examples of beneficial results without making a clear cut dollar and cents comparison.

Costs of Reclamation

The cost of reclamation is broken down into the following four categories.

1. Land leveling.
2. Open drains.
3. Covered tile drains.
4. Leaching without crop.
   Leaching with crop.

Land leveling

The cost of land leveling is very flexible depending upon the length of haul and the type of soil. The cost of leveling in the Imperial Valley during 1950 averaged as low as 12 cents a yard on short hauls where the soil is easy to move and 18 to 20 cents a yard on long hard hauls. A compilation of leveling work on 243 farms during 1950 showed 3,885,481 yards moved on 14,799.6 acres. The average was about 263 yards of soil moved per acre.

The following examples give the general range of leveling costs per acre in the Valley. The average costs of all leveling in Imperial Valley in 1950 was about $42.00 per acre.

Example 1.

114 acres leveled.
122,600 cubic yards moved.
$12,712 total cost of leveling.
$129.05 cost per acre.

Example 2.

181 acres leveled.
54,000 cubic yards moved.
$7020 total cost of leveling
$38.78 cost per acre.

The cost of a survey to establish the proper cuts and fills of a land leveling operation was about $2.50 per acre during 1950.

Open drains

Open drains are an integral part of reclamation as waste ditches are required to carry away the surface waste waters and effluent from tile drainage systems. Shallow drains can be used for surface waste waters, however, deeper drains are required to collect tile drainage effluent. A 7.5 foot drain is generally constructed in order to provide a 12 inch overpour on a 6.5 foot tile drainage outlet.

The excavation cost of open drains in the Imperial Valley averages about 7 cents a yard. This includes smoothing the spoil-bank to form a road on either side of the drain. The drains are excavated with a 3 foot bottom width and a $1\frac{1}{2}$ to 1 side slope. Table 40 gives the volume (cubic yards) of soil removed, per hundred feet for various depths of open drains. A 7.5 foot open drain is required for a 6.5 foot outlet and is outlined in the table.

Table 40. Volume of excavation (cubic yards) per hundred feet of drain with a 3 foot bottom width and $1\frac{1}{4}$ to 1 side slopes.

Drain:	Tenths of foot									
depth: Feet	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0	0	1.2	2.4	3.8	5.2	6.7	8.3	10.0	11.9	13.8
1	15.7	17.8	20.0	22.3	24.6	27.1	29.6	32.3	35.0	37.8
2	40.7	43.8	46.9	50.0	53.3	56.7	60.2	63.8	67.4	71.2
3	75.0	78.9	83.0	87.1	91.3	95.6	100.0	104.5	109.1	113.8
4	118.5	127.4	128.3	133.4	138.5	143.8	149.1	154.5	160.0	165.6
5	171.3	177.1	183.0	188.9	195.0	201.2	207.4	213.8	220.2	226.7
6	233.3	240.0	246.9	253.8	260.7	267.8	275.0	282.3	289.6	297.1
7	304.6	312.3	320.0	327.8	335.7	343.8	351.9	360.0	368.3	376.7
8	385.2	393.8	402.4	411.2	420.0	428.9	438.9	447.1	456.3	465.6
9	475.0	484.5	494.1	503.8	513.5	523.4	533.3	543.4	553.5	563.8

There are a number of items of expense in addition to the excavation costs. Right of ways must be cleared, farm entrances, canal crossing and road crossings must be build and waste outlets and waste pipes have to be provided.

Drain construction costs were obtained from the Imperial Irrigation District on three representative jobs. The costs per mile on the various phases are given in table 41.

Table 41. Costs of 7.5 foot open drain construction per mile for three representative jobs in the Imperial Valley, California.

Item	A	B	C
1. Clearing right of way.	$ 1520.00	$ 600.00	$ 488.89
2. Excavation of drain.	1440.00	1033.33	1466.67
3. Farm and field entrances.	260.00	250.00	211.11
4. Road and canal crossings.	460.00	600.00	1697.77
5. Waste outlets.		783.33	
6. Drain outlet structures.			622.22
7. Replace waste pipe			133.34
8. Install new waste pipe.	560.00	266.67	100.00
Total cost per mile.	$ 4240.00	$3533.33	$ 4720.00

Covered tile drains

The cost of tile drainage is generally dependent upon the spacing of the drainage laterals. In heavier soils the drainage laterals must be closer together to maintain the ground water table at a safe level. During 1950 the cost of tile drainage in the valley generally ranged between $40.00 and $60.00 an acre.

The following tabulation gives the average cost of tile installation during the later part of 1950 in the Imperial Valley.

Installation of tile drainage outlet into open drain.	$50.00
Moving tile installation machine to the property to be tiled.	$75.00

The cost of installing 6.5 foot deep drainage tile per foot by sizes.

4 inch tile - $0.31 per foot
5 inch tile - $0.33 per foot
6 inch tile - $0.36 per foot
8 inch tile - $0.44 per foot
10 inch tile - $1.00 per foot

The costs of tile installation includes the tile, installation, gravel envelope around the tile and back-filling the trench. Consolidating the fill with irrigation water is done by the individual farmer.

If an open drain of sufficient depth is not available a sump can be employed to lift the tile drainage effluent and discharge it into a shallow surface drain. These sumps are installed and operated by the Imperial Irrigation District at no expense to the farmer. The cost on four representative sumps installed during 1950 are given in table 42.

Table 42. Costs of material and installation of drainage sumps, Imperial Valley, California.

ITEM	A	B	C	D
1. Type of sump.	Redwood	Concrete	Concrete	Concrete
2. Size of sump, feet.	5x5x12	8x12	8x12	8x12
3. Build and install sump.	325.00	500.00	500.00	500.00
4. Transite pipe and well points.		350.00		300.00
5. Wiring pump (switch, fuse box and outlet)	50.00	50.00	25.00	50.00
6. 1 or 1½ horse power 110 volt motor and pump assembly.	200.00	225.00	400.00	225.00
7. Install motor and pump.	25.00	25.00	25.00	25.00
8. Provide electrical transformer and power pole.	150.00	175.00	150.00	150.00
9. ¼ and 1¼ mile of power line extension			250.00	175.00
Total cost of sump	$750.00	$1325.00	1350.00	3000.00

The pump is operated by a float on the water surface in the sump and runs intermittently dependent upon the size of the pump and the effluent from the drainage system. The electrical cost of 1½ cents a K.W. will range from $2.00 a month on very small discharges to $38.00 a month for discharges of 500 and 600 gallons per minute. The average monthly cost of operating sumps in the Imperial Valley is about $10.00.

Leaching

The cost of leaching will vary depending upon; (1) the amount of work that is necessary prior to leaching; (2) the duration of ponding time; (3) the type of leaching; and (4) the work required to put the land back into production following leaching. The following are some of the cost items connected with the actual leaching:

Preparation costs prior to leaching.

1. Engineering costs (dike locations) - - - - - $ 2.50 acre
2. Construction of contour dikes- - - - - - - - 5.00 acre
3. Subsoiling on heavy soils- - - - - - - - - - 5.00 acre
4. Control boxes in leaching dikes to regulate water elevation- - - - - - - - $ 1.00 acre

Cost during leaching

1. Gate charge for delivery of water - - - - - - $ 0.25 day
2. Water costs without crop- - - - - - - - - - - 0.00
3. Water cost with crop such as rice, sesbania or tullies- - - - - - - - - - - - $ 1.30 ac. ft.
4. Labor costs per man per day - - - - - - - - - 5.00 day
5. Discing between ponding periods - - - - - - - 3.00 acre
6. Cost of seed rice - - - - - - - - - - - - - - 1.37 acre
7. Cost of seed sesbania - - - - - - - - - - - - 4.00 acre
8. Cost of seeding rice by air - - - - - - - - - 1.37 acre
9. Cost of seeding sesbania by air - - - - - - - 2.00 acre

Costs following leaching

1. Smoothing out borders - - - - - - - - - - - - $ 5.00 acre
2. Land leveling (level touchup) - - - - - - - - 4.00 acre
3. Replacing fertilizers lost due to leaching- - 6.00 acre

The following tabulation gives an indication of the leaching costs on a heavy textured 160 acre tract both with and without a leaching crop.

Item	With crop	Without crop
1. Acres.	160	160
2. Days leaching without crop.	18	106
3. Days leaching with rice.	88	---
4. Engineering costs.	$400.00	$400.00
5. Construction of contour dikes.	800.00	800.00
6. Subsoiling prior to leaching.	800.00	800.00
7. Control boxes.	160.00	160.00
8. 106 day gate charge	26.50	26.50
9. Water cost for rice crop 3.6 ac.ft. per acre.	748.80	---
10. Labor costs ($5.00 a day for an average of 1 man).	530.00	530.00
11. Discing between ponding periods.		480.00
12. Cost of rice seed.	219.20	
13. Cost of seeding rice by air.	219.20	
14. Smoothing out borders.	800.00	800.00
15. Land planning (level touchup)	640.00	640.00
16. Fertilizer required to replace that lost during leaching (all nitrogen lost and some potassium).	960.00	960.00
Total cost - - - -	$6303.70	$5596.50
Cost per acre- - -	$39.40	$34.98

Benefits from Reclamation

The effectiveness of reclamation by tile drainage and leaching is primarily indicated by crop responses and increases in production. In general the results have been excellent and in several cases the installation of tile drainage and subsequent leaching has more than paid for the reclamation costs with the increase in crop production the first year. Results on crop increases to date indicate that there is an increase of about 10 percent per year for at least five or six years following the reclamation practices.

Fertilizers show a marked effect upon the crop growth, however, no amount of fertilizer will produce a normal crop growth on soils that have a high salt content in the surface foot of soil and a water table within several feet of the surface.

Table 43 gives crop increases in the Imperial Valley that were due to land leveling, tile drainage and leaching out the toxic saline elements.

A typical leaching operation is shown in figure 11-A. The land was relatively level and permitted the construction of straight leaching dikes. The dikes averaged five feet in bottom width, two feet wide at the top and were about two feet high. The leaching water averaged one foot in depth over the plots. A typical control box used in regulating the depth of water in the leaching ponds is shown in figure 11-B. The control boxes are generally made of redwood. They are made in various sizes depending on the size of the area being leached. Gate boards are used to regulate the depth of water in the ponds.

Two examples of leaching dike construction are shown in figure 12. If the land has a uniform slope the dikes can be constructed in a straight line as shown in figure 12-A. The spacing of the dikes will be dependent upon the slope of the land. If the land is fairly uneven, dikes similar to the ones shown in figure 12-B will be required. The dikes shown in both examples are constructed on the contour to maintain an average leaching water depth at one foot in the ponds.

LEACHING SPECIFICATIONS IN IMPERIAL VALLEY

In February of 1949 the Imperial Irrigation District passed and adopted the following procedure for the delivery of leaching water.

1. Applications for leaching water shall be made at the Division office of the area in which the property is located.

2. Applications for leaching water shall not be approved for delivery of water until adequate protection has been provided the adjacent properties against flooding or encroachment of ground water from the ponded area.

Table 43. Production increases in the Imperial Valley attributed to reclamation practices.

Farm No.	Acreage Acres	Land leveled	Tile drainage installed Year	Leached	1944	1945	1946	1947	1948	1949	1950	1951
												Crop production in pounds per acre per year
1	160	Yes	1947	Yes				B-2200 ▯	B-4600	F-3300	F-3300	B-4800
2	160	Yes	1947	Yes				F-1120 ▯	F-1624	F-3300	W-3000	W-8538
3	320	Yes	1947	Yes				A-8835 ▯	A-17367	A-17498	A-17670	A-18259
4	240	Yes	1947	Yes	Out of production			0 ▯	B-2227	A-11780	A-11780	A-12369
5	120	Yes	1949	No						S-44000 ▯	S-46000	
6	10	Yes	1947	No	Given in boxes per acre			L-200 ▯	L-270	L-275	L-245	
7	10	Yes	1947	No	Given in pounds per tree			D-380 ▯		D-500	D-510	
8	160	Yes	1947	No	Out of production			0 ▯		B-2000		
9	140	Yes	1949	Yes				Out of production		0 ▯		B-1100
10	160	Yes	1949	Yes					A-8835 ▯	B	A-17670	
11	100	Yes	1945	Yes	Out of production ▯						A-8835	C-75
12	100	Yes	1945	Yes	Out of production ▯						A-8835	Z-160
13	15	Yes	1947	Yes		Out of production		0 ▯	Leached	B-500	Leached	S-30000
14	40	Yes	1950	No					Out of production		0 ▯	A-15078
15	40	Yes	1950	No							A-5380 ▯	A-15078
16	180	Yes	1944	No	0 ▯	B-950		A-14136	A-14725	A-14725	F-2240	F-2240
17	54	Yes	1947	No	A-5300	A-5222	A-5111 ▯	A-1500	B-333 F-543	A-667 F-455	A-7200	A-8640 F-1785

B = Barley in pounds per acre
F = Flax in pounds per acre
W = Wheat in pounds per acre
A = Alfalfa in pounds per acre
S = Sugar beets in pounds per acre
L = Lemons in boxes per acre
D = Dates in pounds per tree
C = Cantelopes in crates per acre
Z = Lettuce in crates per acre
▯ = Indicates period the tile drainage was installed.

FIGURE 11 A--PONDS FOR RECLAMATION OF SALINE SOILS BY LEACHING, IMPERIAL VALLEY, CALIFORNIA

FIGURE 11 B-- DIKES AND CONTROL BOX USED IN REGULATING DEPTH OF WATER IN THE LEACHING PONDS.

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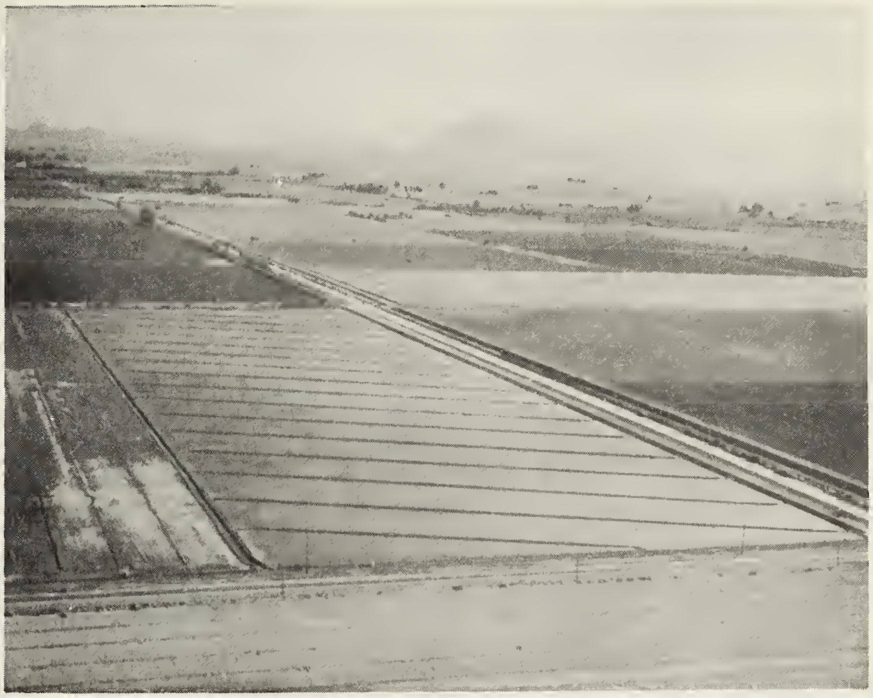

FIGURE 12 A--LEACHING OPERATION ON LAND WITH A UNIFORM SLOPE.
(CREDIT J.D. HESS)

FIGURE 12 B--LEACHING OPERATION ON LAND THAT IS SLIGHTLY UNLEVEL. (CREDIT J.D. HESS)

3. The delivery of leaching water on approved applications shall be subject to availability of water over the demand for water on the irrigation of crops.

4. The charge for water delivered for leaching purposes shall be 25 cents gate charge, for each 24-hour run.

5. The land shall be well leveled and have adequate facilities to permit movement of water through the soil for removal of excess salts.

6. The land shall be contour bordered on not more than .3 intervals. The base of the borders to have sufficient width to maintain a top width of two feet. The height of the borders to be at an elevation one foot above the elevation of the water surface required to pond water not more than one and one-half foot depth on the land.

7. Substantial control boxes shall be installed in borders for safe control on passage of water over the field.

8. When ponding water adjacent to property lines or public roads,
   (a) The ponded area shall be held back 75 feet from the property line and intercepting drain constructed paralleling the field borders.
   (b) The intercepting drains shall be constructed to specifications to be determined by texture of soil and stratification.

9. When there is not sufficient information available to determine requirements for safety of adjacent land and additional field work is required on (a) test wells, (b) profiles, (c) plotting profiles, (d) semi-permanent test wells, and advance deposit shall be obtained to cover the estimated cost of the work.

10. Where the ponded area parallels District drains, the same shall be held back 75 feet from the right-of-way lines and intercepting drain constructed paralleling the field border. The depth of the intercepting drain to be determined by the soil classification and depth of drain.

11. The leaching period shall not exceed 90 days on any one continuous leaching period.

12. Approval of applications for leaching water shall be subject to,
    (a) Field inspection of preparatory work prior to approval for delivery of water.
    (b) If the work has not been completed to comply with regulations the landowner shall be informed of the additional work required and approval for the delivery of water withheld pending completion of the work.

13. The release of water from ponded area during the leaching period shall not exceed a maximum of one acre-foot per 40 acres of ponded area during leaching operations.

14. For dewatering the ponded area -
    (a) The landowner shall inform the Division Superintendent of the date he desires to begin release of the water.
    (b) The Division Superintendent shall designate the maximum quantity (second feet) that may be released at any one time to District drain.

15. The landowner shall be responsible for all damage resulting from ponding operations to District facilities and private properties.

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